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VENUS REVEALS ITS SECRETS
(Collection of Articles)

FOREIGN TECHNOLOGY DIVISION

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EDITED MACHINE TRANSLATION

VENUS REVEALS ITS SECRETS (Collection of Articles)

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* ye initially, after vowels, and after ъ, ь; e elsewhere. When written as ё in Russian, transliterate as yё or ё. The use of diacritical marks is preferred, but such marks may be omitted when expediency dictates.

This book in popular form tells about the next stage of the Soviet program for the investigation of the planet Venus with the aid of the automatic space stations, "Venus-5" and "Venus-6."

The reader can follow the whole history of man's investigations of Venus, beginning with the most ancient times and continuing up to the present. He will become acquainted with the flights of the space stations "Venus-1," "Venus-2," "Venus-3" and "Venus-4," which helped to reveal certain mysteries of the planet and simultaneously defined more accurately the possibilities of subsequent investigations.

In the flights of the space stations "Venus-5," and "Venus-6" data were received about the atmosphere of Venus and the characteristics of interplanetary space, which enriched man's knowledge of the universe; and these flights were genuine triumphs for Soviet science and technology.

PREFACE

The contemporary epoch – a time of the greatest achievements of natural science and technology – is characterized by the ever increasing role of space research, which is discovering new possibilities for the more profound understanding of nature by man.

The investigations of circumterrestrial space are matched by the study of outer space; the flights of man – by the launchings of automatic space stations to the planets of the solar system and to the moon.

We are witnesses of the coming to truth of the prophetic words of the outstanding Russian scientist, the founder of astronautics, Constantine Edwardovich Tsiolkovsky: "Mankind will not remain forever on the earth, but in quest of space and the universe will first timidly penetrate beyond the limits of the atmosphere, and then, will conquer the whole of circumsolar space."

Man with ever increasing persistence is penetrating into outer space, studying it and making it serve his own interests.

Only the launching of artificial earth satellites has made it possible to understand the enormous effect on the atmosphere and the ionosphere of earth being rendered by interplanetary space and what the processes are developing in it.

Satellites of the "Meteor" meteorological system have provided systematic transmission of data about processes, occurring in the atmosphere, and thus have made it possible to warn ships and aircraft in time about approaching storms and typhoons, and to more accurately predict weather conditions in various regions of our planet which has had enormous economic significance for all countries of the world.

Millions of people, located in the remotest corners of our country, have become very accustomed to receiving the transmissions of Central Television and videotelephone communication via the satellite "Molniya-1" using the "Orbit" ground network receiving stations.

The first manned experimental space station in circumterrestrial orbit in history was created from the spaceships "Soyuz-4" and "Soyuz-5."

The flights of the "Zond-5" and "Zond-6" stations were the first to solve the problem of the return to earth of an automatic interplanetary station.

The direct systematic investigations of Venus, begun by the automatic station "Venus-4" in 1967, are being continued.

One more important space experiment has been successfully completed. The automatic space stations "Venus-5" and "Venus-6," launched on January 5 and 10, 1969, successfully reached the planet Venus. On May 16 the descent vehicle of the station, "Venus-5," and on May 17 - of the station, "Venus-6," after aerodynamic breaking in the upper layers of Venus's atmosphere effected a smooth descent by parachutes in different regions of the planet and carried out the sounding of its atmosphere.

Message bags of the Soviet Union with a bas-relief of Vladimir Il'ich Lenin and the Emblem of Union of Soviet Socialistic Republics were delivered to the surface of the planet.

For the first time in the history of astronautics scientific investigations of another celestial body were carried out simultaneously in practice in two of its different regions. New scientific data about the physical properties of Venus's atmosphere were obtained. One more step in understanding the universe had been made.

THE PLANET OF ENIGMAS

On the horizon Venus in its mysterious, alluring brilliance appears to the terrestrial observer in the evening, and in the morning, and in remote antiquity people assumed that it was two stars: the evening star - Vesper [Hesperus] and the morning star - Lucifer [Phosphorus]. However the ancient Greek Scientist Pythagoras already knew that in actuality this was one star. Later this star was given the name of the goddess of love and beauty - Venus, who personified the image of the beautiful woman.

For designating the Sun, Moon and planets astronomers use symbols of very ancient origin. The symbol for Venus is a representation of a hand mirror - the emblem of feminity and of beauty.

In the observing Venus, scientists established that it moves around the Sun in an almost circular orbit at a mean distance from it of 108 million kilometers; its complete revolution around the sun it accomplishes in 224 days, 16 hours, and 49 minutes, and its average velocity along its orbit is 35 kilometers per second.

Venus is the closest planet to us. In its motion along its orbit it periodically occupies relative to the Sun and Earth two diametrically opposed positions, which have received the names inferior conjunction, when Venus is located between the Earth and Venus. The minimum distance between Venus and the Earth is about 42 million kilometers (inferior conjunction) and the maximum - 258 million kilometers (superior conjunction).

?

The relative position of the Earth, Venus, and the Sun in inferior conjunction, when they are located in a straight line, is called the phenomenon of the transit of Venus across the Solar disk. This pheno enon can be observed even with the naked eye. However not everyone can become a witness of this phenomenon, since the periodicity of a transit of Venus is 8; 105.5; 8 and 121.5 years. In the past century this phenomenon was observed on December 9, 1874 and December 8, 1882. And only June 8, 2004 and June 6, 2012 will it be repeated again.

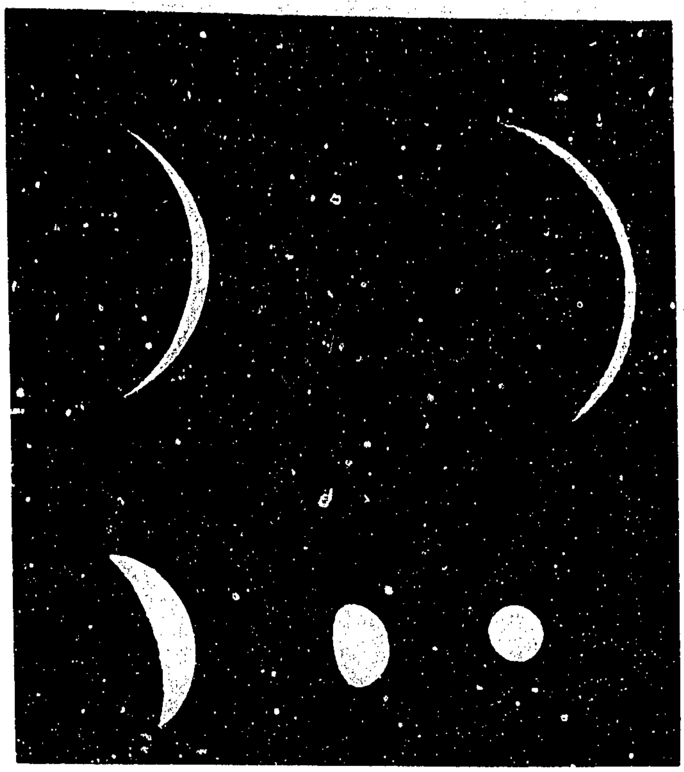
Knowing the distance of Venus from the sun, its velocity along its orbit, the perturbations, which it renders on other planets, scientists have determined that the radius of this planet is approximately equal to 6100 kilometers, its mass is 0.8136 of the mass of the earth, and its density is 5.12 grams per cubic centimeter which is somewhat greater than the density of the Earth.

Inasmuch as Venus and the Earth are close in respect to sizes, mass and the amount of heat, received from the Sun, they are sometimes called sister-planets.

In 1610 the Italian astronomer Galileo, observing Venus through a telescope, first detected and described the sequential variation on its phases, analogous to Moon. He was not at first confident in the correctness of his observations and decided not to make them known. Thus Galileo encoded the information about his discovery in a Latin anagram phrase and only later, finally convinced of the correctness of his assumption, did he decipher it, having transposed in it the letters: "Mother of love imitates the forms of Cynthia." Mother of love is the goddess Venus, and Cynthia is one of the ancient names of the moon.

In inferior conjunction, when Venus is located at its closest distance to the earth, it always has its dark side turned toward us, and thus we never see it in its largest phase. Moving away from this "new Venus" position, the planet assumes the shape of a crescent,

the diameter of which is the smaller, the wider is the crescent. The complete disk of Venus is visible at an angle of 10 degrees to the sun, the maximum crescent - at an angle of 64 degrees.



Views [phases] of Venus in a telescope.

In 1761 the foremost Russian academician, Mikhail Vasil'yevich Lomonosov, observing Venus at the time of its transit across the Solar disc, first detected on the planet a thick atmosphere, about which in his work "The Phenomenon of Venus on the Sun Observed at the St. Petersburg Imperial Academy of Sciences on May 26, 1761" wrote: "According to his notes Professor Lomonosov reasons that the planet Venus is surrounded by a significant air atmosphere, which might not be as large, as the one which enshrouds our terrestrial sphere."

Venus's atmosphere was so "significant" that even the powerful, present-day, optical telescopes are not strong enough to see through its dense cloudy curtain, which, as a yashmak [veil] of an Eastern beauty, conceals here appearance from us.

This is why the velocity of Venus's rotation have for so long a time remained unknown around its axis, its temperature, pressure and the composition of its atmosphere, the aggregate state of its surface - stony hardness, water smoothness or molten lava - have for so long time remained unknown. Scientists have not been able to state confidently what kind of relief the planet has.

By visual or by photographic means they have managed to discern on Venus's disc only vague dark or light spots. They have variable shapes and are observed only during the course of a few days or weeks. Some of them are unstable and two-three days after their appearance they disappear from the bright background of the planet. But rather stable spots of large sizes are also encountered.

With the development of science and technology new methods of investigating the planets of the Solar system have appeared: spectrographic, radio astronomical, and radar methods.

Radio observations in essence marked the beginning of a new stage in the investigation of Venus, since only radio waves of specific frequencies were able to bring from the surface of Venus, securely hidden from observations by the dense atmosphere, certain physical characteristics, which made it possible to construct hypothetical models of Venus's atmosphere.

New information about Venus was obtained with the aid scientific equipment, lifted into the stratosphere by balloons.

Radar methods made it possible to determine the direction and period of Venus's spin. It was ascertained that Venus rotates in a direction, opposite to the rotation of the Earth and of the other planets of the Solar system. The period of rotation of Venus relative to the stars is about 244 terrestrial days. Let us remember that the period of the orbital motion of Venus (the Venusian year) is equal to 224.7 terrestrial days. A consequence of this fact is that the Sun during a Venesian year rises and sets twice on the horizon of the planet.

The inclination of the axis of rotation of Venus is approximately 20 degrees less, than that of the earth, i.e., the axis is practically perpendicular to the plane of the ecliptic, and this means on Venus there is no alteration of seasons.

But what does the atmosphere of Venus consist of and what are its clouds, which, reflecting sunlight exceedingly well, make this planet the brightest luminar [heavenly body] in the sky (of course, that is, except the Sun and Moon)? These questions have remained unanswered.

Long ago in the atmosphere of Venus above the cloud layer carbon dioxide was detected by spectral measurements, and many scientists considered that its concentration was not more than 5-10 percent, and that the basic component in analogy to the terrestrial atmosphere was nitrogen.

The clouds of Venus, as the scientists assumed, should consist of water vapor or ice crystals. The attempts to spectrographically detect bands of water vapor were unsuccessful, and only in the 60's the photographing of the spectra of Venus from a balloon at a height of 27 kilometers above the Earth brought the desired results. At this height the amount of terrestrial water vapor is so small that it cannot affect the results of spectrographic investigations of Venus. In the spectrum of the atmosphere of Venus absorption bands of water vapor were discovered. But it would be difficult to make any statement about the amount of water vapor.

Some scientists then assumed that they would also be able to observe from the spectrum signs of the presence on Venus of other gases, in particular oxygen, nitrogen and carbon monoxide, but they were not able to confirm their hypothesis, because they did not have strong enough proofs.

Several years ago French scientists detected in Venus's atmosphere traces of hydrochloric and hydroflouric acid vapors and

even carbon-monoxide gas. The presence of these substances could indicate active volcanic phenomena.

Concerning the temperature conditions of Venus we, right up to the beginning of the radio-astronomical approach to the planet in the mid-50's, knew only that it was possible to obtain them by radiometric observations. Measurements of the infra-red, thermal radiation of Venus, carried out from Earth with a radiometer, yielded values of temperature above the clouds of the planet during the day and night of about -35°C. These results were not very surprising. Indeed in the terrestrial stratosphere, at a great height above the Earth, the temperature is low and varies little from day to night, and from the poles to the equator.

The continuous overcast and the proximity of Venus to the Sun led the scientists to the idea that the climatic conditions on this planet were similar to those which existed on Earth during the Carboniferous Period of its history. Then under the clouds in the moist atmosphere of the Earth greenhouse, hot-house climate was created and thick vegetation developed vigorously.

A severe blow to these concepts was inflicted by the measurements of the radio emissions of Venus, carried out in recent years. Repeated many times, they indicated that the physical conditions on this planet were entirely unsuitable for life. They were excessively hot there.

The measurements of the Venusian radio emissions on the centimeter band (a wave length of more than 3 centimeters) yielded an unexpectedly high magnitude of temperatures - from +250 to +400°C.

The millimeter waves indicated temperature somewhat lower - about 130°C. The assumption arose that in the cloudy cover of Venus there is absorption of millimeter radiation. At the same time measurements of infra-red radiation yielded a temperature with a mean of +40°C.

Let us note that from the data of these direct observations of Venus it was known that the density of this atmosphere as greater than that of the Earth's. This motion was suggested to the scientists by their observations of Venus's crescent which is much longer than the Moon's crescent. Sometimes its tips even merged, forming an ultrafine ring. This can be explained by the phenomenon of refraction - by the bending of light rays in a medium of variable density, and, as is known refraction is greater, the greater is the density gradient.

The data obtained about the high temperature of the surface of Venus confirm these assumptions, because high temperatures also imply high pressure, possibly, up to several tens of atmospheres.

Inasmuch as the data obtained about the temperature conditions of Venus, measured by various methods, are completely realistic, scientists should on their bases be able to explain the structure of Venus's atmosphere. Several variant models of the structure of the Venusian atmosphere have been advanced, and preference has been given to the greenhouse model.

The greenhouse model. According to this model it is assumed that the Venusian atmosphere contains a large quantity of carbon dioxide and water vapor, forming a thick cloudy cover, which at great hights consists of ice crystals. Thus such a covering possesses great reflective capability (which also explains Venus's brightness) and poorly transmits solar thermal radiation.

But, inasmuch as the heat flux from the Sun is great, part of it nevertheless penetrates through this curtain and reaches the surface of the planet, heating it and the subcloud layers of the atmosphere. And the cloud layer plays the role of the glass in a greenhouse - it prevents the return of the heat from the Venusian surface to outer space (radiative radiation), due to which the subcloud layer of the atmosphere is warmed up until it approaches thermodynamic equilibrium.

The landscape of Venus appears inhospitable and unattractive before us: there is no water on the surface - all the moisture is in the heavy, thick atmosphere, saturated with carbon dioxide, and almost devoid of oxygen. The sun and stars are hidden by the dense clouds. It is quiet, dark, and hot.

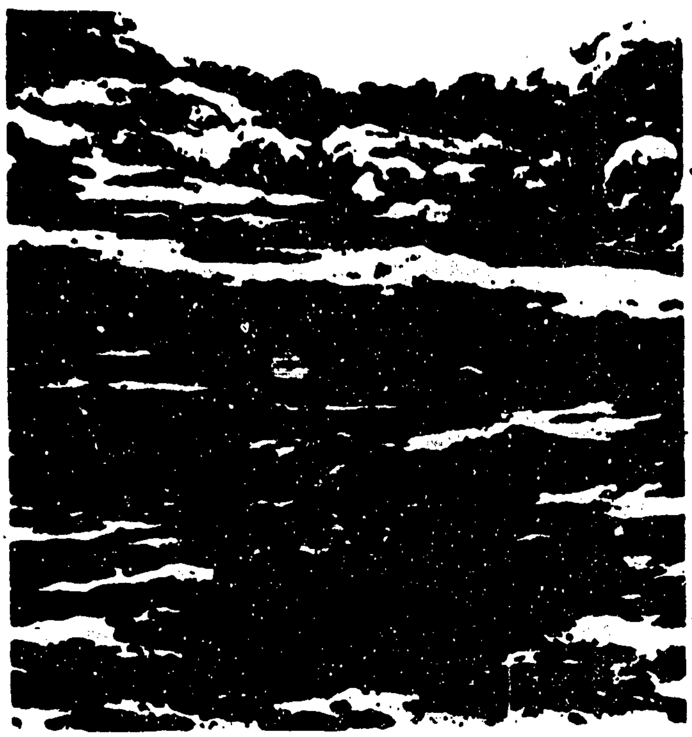
The Eolospheric model, or the thermal-sphere model. As was noted above, it has been ascertained by radar methods that Venus rotates extremely slowly therefore according to this model one of its hemispheres is heated to a very high temperature, the second is considerably cooled. Convective fluxes of great force (their velocity is 150-200 meters per second), appear carrying along after the soil particles; as a result of the molecular friction of the air and the particles carried along with it the atmosphere is vigorously heated up.

Due to this the lower part of the Venusian atmosphere to a height of up to 20 kilometers is filled with dust particles. And inasmuch as the clouds are white, this hypothesis assumes that the dust is white powder of carbonates (calcium and magnesium).

The landscape, which the Eolospheric model sketches for us, is as unattractive, as the landscape of the greenhouse model.

Ionospheric model. In constructing the preceding models the scientists based their assumptions on the fact, that the high temperature pertains to the surface of Venus as well as to the lower layers of its atmosphere. In both cases the atmosphere should have a considerable extent (20-30 kilometers up to the upper boundary of the cloud layer) and a large mass (the pressure near the surface is tens of atmospheres). The authors of the ionospheric model the results of the radio observations - the high temperature of Venus - explain there by the large degree of ionization of the upper layers of the air shell of the planet; and if in these layers of the atmosphere a rather large concentration of free electrons is formed, the ionosphere can be non-transmissive

centimeter band for radio emissions and transmissive for millimeter band emissions. However this assumed high electron density is difficult to explain: it cannot be caused by the ultra-violet radiation of the Sun, or by the corpuscular fluxes, coming from the Sun. Furthermore, if the ionosphere with a high concentration of electrons is non-transmissive for centimeter radio waves, then it will be even more non-transmissive for decimeter waves. Whereas the radar observations of Venus show that the decimeter waves are reflected from the hard surface of the planet, and therefore the ionospheric model does not agree with the radar observations.



Landscape of Venus.

As is apparent, there are deficiencies in the hypothesis, and the scientists are justified in calling Venus the mysterious planet. In spite of the whole powerful technology of planetary astronomy - radiotelescopes and radar, equipped with the most

sensitive quantum amplifiers and gigantic antennas, optical telescopes with infra-red receivers and improved spectroscopic equipment - has been directed to obtaining new information about the physical characteristics of this planet, the interpretation of the obtained data has been eqivocal and has given rise to diverse hypotheses.

The investigations of the true physical conditions on Venus, which differ acutely from terrestrial conditions, are of great scientific interest. These irritating questions can be solved only with the aid of robot space stations, sent to the planet and flying around it at a low altitude or descending directly into the depth of its atmosphere or even to its surface.

ON THE WAY TO VENUS

On October 4, 1957 a Soviet man made the first and most important step toward overcoming terrestrial gravitation – the first artificial satellite of the earth was put into circumterrestrial orbit. The era of manned exploration of the universe, forecasted by the founder of the school of jet propulsion – the great Russian scientist Constantine Edwardovich Tsiolkovsky – had begun.

Scientists now had in their hands a new instrument, with the aid of which they would be able to conduct direct investigations of outer space.

As a result of the enormous creative work of Soviet scientists, designers, engineers, workers and technicians a multistage rocket was created, the last stage of which developed the second cosmic velocity [escape velocity] – 11.2 kilometers per second. The achievement of escape velocity opened the possibility for interplanetary flights along previously assigned trajectories. This made possible in 1959 with the aid of automatic stations the beginning of the systematic investigation of interplanetary space, the Moon and Venus.

To investigate Venus it was necessary to solve a whole group of the most complicated problems.

It was necessary, first, using the laws of celestial mechanics, to ensure such a trajectory of flight, such a condition of flight of the space station, that, after having overcome the force of terrestrial gravity and moving under the effect of the Sun's attraction, it could

at an assigned point in outer space encounter Venus. The relative position of the Earth and Venus in space continuously varies due to the difference of their periods of revolution around the Sun, however each of the configurations is repeated every 584 days, and, as was already stated above, at the time of inferior conjunction (Venus is located between the Sun and the Earth) the distance from the Earth to Venus is minimum, and in superior conjunction (Earth and Venus are positioned on different sides of the Sun) the distance from the Earth to Venus is maximum. This indicates the substantial effect of the selection of the flight paths.

Secondly, the selected flight path should correspond to the least possible velocity of the space station at the end of the propelled section of flight – this makes it possible with the available power of the engines of the rocket-carrier to send the station into space with the maximum payload.

Thirdly, the flight time should be minimum, because in proportion to the increase in the duration of the flight the danger of the collision of the space station with micrometeroids and the probability elements of the equipment of the space station going out of order under the effect of the factors of the space medium increases.

Fourthly, the initial values of the parameters of the interplanetary trajectory should be strictly maintained, because errors in the velocity by several meters per second or in the orientation of the station by several degrees make a rendezvous with Venus impossible.

Fifthly, to ensure reliable radio communications at the time of the encounter of the station with Venus it is desirable, that Venus be as near as possible to the Earth.

Sixthly, the selected trajectory should ensure the least possible speed of entry into Venus's atmosphere, because this decreases the

overloads and the amount of heating, acting on the descent vehicle which makes it possible to decrease the design weight of the descent vehicle and its heat shield.

Inasmuch as it is not possible to select a trajectory, which is satisfactory to all these requirements, the problem consists in selecting the most advantageous interplanetary trajectory.

Let us try to select a trajectory, which corresponds to a flight to Venus along shortest possible path.

Such a flight can be accomplished, if the station will "fall" to the Sun in a straight line, i.e., when at the time of the encounter with the station Venus is located in inferior conjunction.

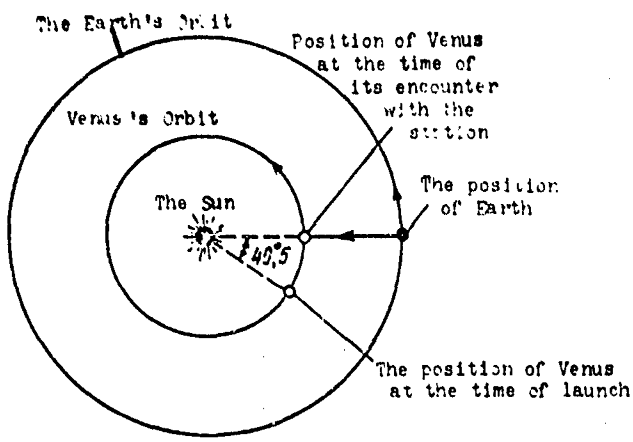
With such a trajectory the passage time will last about 25 days and the path covered will be equal to a little more than 42 million kilometers.

In order that the station "falls" to the Sun, its velocity in its orbit relative to the Sun after launch should equal zero. To accomplish this it is necessary to import to the station a velocity of 29.76 kilometers per second (the heliocentric velocity of the Earth) and to send it in a direction, opposite to the motion of the Earth in its orbit around the Sun. Furthermore, it is also necessary to overcome the force of terrestrial gravity. As the calculations indicate, the velocity of the station to ensure its "fall" to the Sun should equal 31.8 kilometers per second. Such velocities at the contemporary stage of the development of technology are impossible to create. Thus it is simpler to leave the solar system, than to "fall" to the Sun.

There is one more substantial deficiency, connected with a flight to Venus along the shortest possible path — at the time of its encounter with the planet we will not be able to receive any information from on board the station. Solar noises will "jam" all signals from the station, since in this case Venus will be located in inferior conjunction.

Let us now examine a second, advantageous (in an energy regard), flight trajectory.

This trajectory is tangential both to the initial, and to the final circular orbits (of the Earth and Venus), and for the flight along it comparatively small expenditures of propellant are required. However, a flight along such a trajectory also has its negative aspects.



A diagram of the relative positions of Venus and of Earth in a direct flight to Venus.

First of all there is the complexity of inserting the station into this flight trajectory. The point is that at the boundary of the sphere of the Earth's effect, where the attractive forces of the Earth and Suns are equalized (this sphere has a radius of 900 thousand kilometers, and the Earth is its center), the velocity of the station should be 2.5 kilometers per second and it should be guided strictly in a direction, opposite to the motion of the Earth. Moreover this trajectory requires so accurate a realization that an error in the velocity in guiding the station of one meter per second will result in the station flying by Venus at a distance of 70 thousand kilometers.

Let us assume, that the station has been inserted into the calculated trajectory. Then to fly it to its target will require five months and the distance between the Earth and Venus at the time of the encounter of the station with Venus will be about 90 million kilometers.

Thus having selected the path to Venus with a minimum fuel expenditure, thus we complicate the insertion of the station into its flight trajectory, by lengthening the time of the flight and the distance between the Earth and Venus at the time of the encounter.

Let us now examine one of the intermediate variants. This variant corresponds to trajectories, along which at the present time flights of robot space stations to Venus are being accomplished.

In moving along such trajectories the flight time of a station is from 3 to 4 months, and the distance between the Earth and Venus at the time of the encounter is approximately 70 million kilometers. The Sun in this case does not disturb the radio communications.

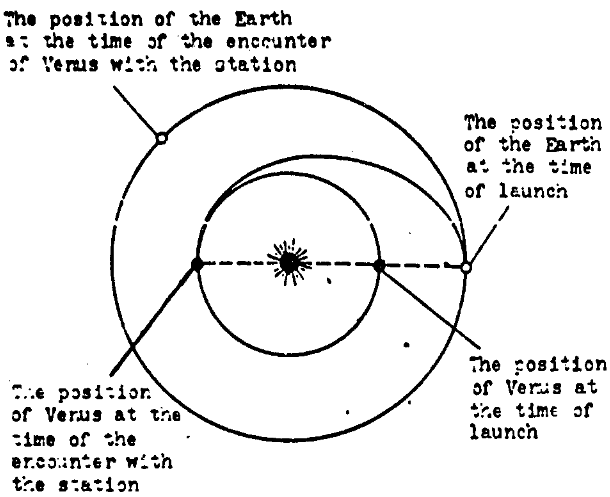


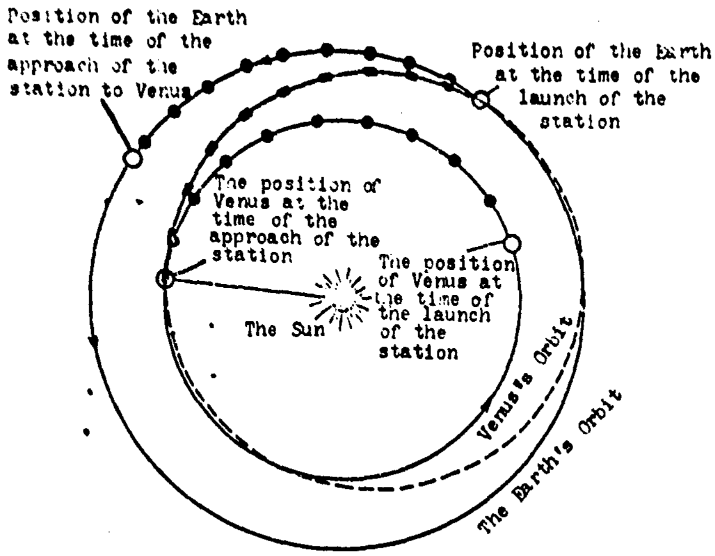
Diagram of a flight to Venus along a Hohmann Orbit [with minimum fuel expenditure].

It is true this is an inconvenience - this accurate launch date, which the astronomical clock peremptorily dictates to us.

A flight can be accomplished when the Earth at the time of the take-off of the station it leads Venus in its angular motion around the Sun by approximately 45°.

The first egress on an interplanetary course to Venus was

undertaken on February 12, 1961, when from on board a heavy Earth satellite the Soviet automatic station "Venus-1" with weight of 643.5 kilograms was launched in the direction of the planet.



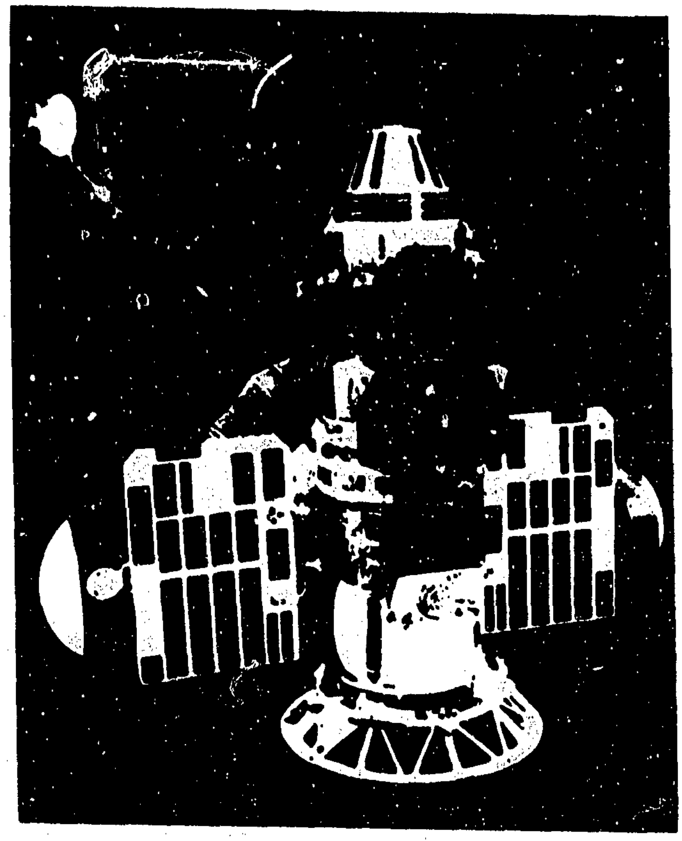
The optimum trajectory of a flight of a robot space station to Venus.

The basic tasks in launching this station were: the checking of methods of inserting the space object on an interplanetary course, the checking of ultra-remote radio communications and of the controlling of a space station, a more precise definition of the scale of the Solar system and the carrying out of a number of physical investigations in outer space.

Communication with the station "Venus-1" was maintained until February 27, 1961, when the distance from the Earth to the station was 23 million kilometers. At that time this was a record for distant outer space communication.

The first attempt by American scientists to launch the spacecraft "Mariner-1" in July 1952 to Venus was unsuccessful. Right after the launch due to trouble in the control system the rocket deviated from its assigned course and was blown up.

In August 1962 the American space vehicle, "Mariner-2", was launched toward Venus.



The Robot space station "Venus-3".

The flight of "Mariner-2" was successful. On December 14, 1962 this space vehicle flew past Venus at a distance of about 35 thousand kilometers and obtained the first data about the planet. The instruments, mounted on the space vehicle, reported that Venus has no magnetic field or radiation belts. Whether this was true, was unknown. It was necessary to check the obtained data.

This came in November 1965. Two automatic stations - "Venus-2" and "Venus-3" were sent together on the way to mysterious planet.

The station, "Venus-2", was launched on November 12, 1965, the station, "Venus-3", - on November 16, 1965.

Each of the stations consisted of two hermetically sealed compartments - an orbital and a special compartment. The special

compartment of "Venus-3" was a descent vehicle, made in the shape of a ball with a diameter of 900 millimeters.

A message bag was placed in the descent vehicle - a metallic globe of the Earth with the contours of the continents engraved on it. Inside the glove was a medal with the emblem of our country on it.

The measurement of the parameters of the flight trajectory of the stations and the prognostication of their movement were carried out with special on-board and ground complexes of radiometering devices and computing centers.

As a result of the trajectory measurements, carried out after the insertion of the station "Venus-2" into interplanetary orbit, it was determined that the flight trajectory of the station was close to the calculated trajectory, and therefore it was not necessary to carry out a correction. On February 27 the automatic station "Venus-2" passed at a distance of 24 thousand kilometers from the surface of the planet.

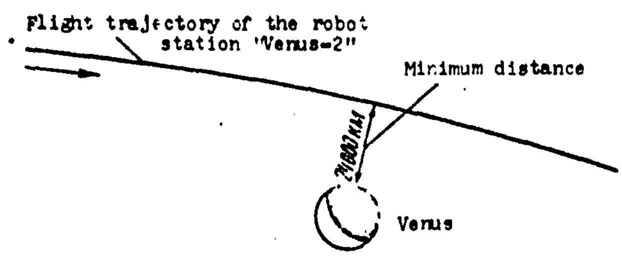


Diagram of the flight of the station "Venus-2".

The correction of the flight trajectory of the station "Venus-3" was carried out on December 26, when the station was located at a distance of about 13 million kilometers from the Earth.

The processing of the trajectory measurements, carried out in the period from the time of the correction until February 15, 1966 inclusive, indicated that the actual trajectory of the station "Venus-3" differed little from the assigned trajectory for hitting the planet.

Pennant of the "Venus-3" station.

On March 1, 1966 the robot space station "Venus-3" reached Venus and delivered the first message bag to its surface. Thus, the first interplanetary course was plotted and the possibility of reaching the planets of the Solar system was proved.

During the time of the flight with the station "Venus-3", 63 communication transmissions were carried out, with the station, "Venus-2" - 26 communication transmissions.

The experiments carried out with the help of the robot stations "Venus-2" and "Venus-3" made it possible to solve a number of important problems of interplanetary flights and to obtain scientific data about outer space and circumplanetary space in the Annum Year of the Quiet Sun. The voluminous and diverse material of the trajectory measurements was of great value for studying the problems of ultra-remote communication and interplanetary flights.

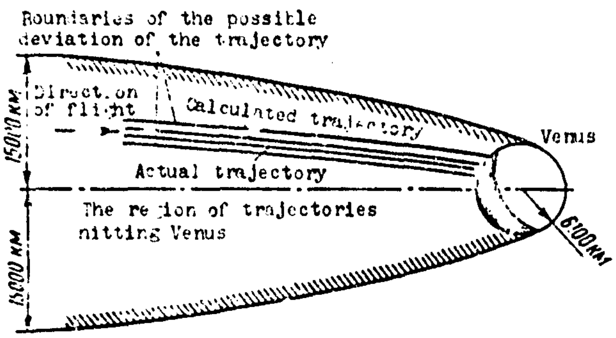
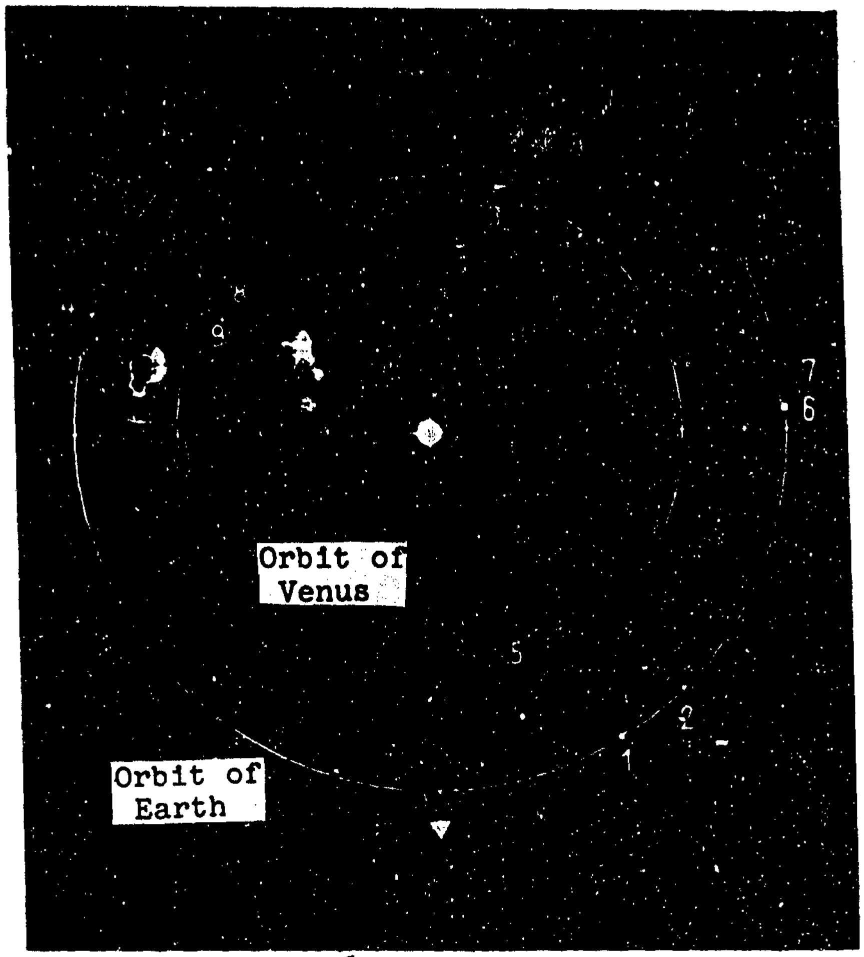


Diagram of the approach of the station, "Venus-3", to the planet Venus.

During the flight of "Venus-2" and "Venus-3" the physical conditions in interplanetary space were investigated: magnetic fields, cosmic rays, low-energy, charged particle fluxes, solar plasma fluxes and their energy spectra, cosmic radio emissions and micrometeroids.

Specifically, the flights of "Venus-2" and "Venus-3" showed that the operational conditions of interplanetary stations in direct proximity to the planet Venus have so far been poorly studied - upon approaching the planet a temperature increase was observed,

exceeding the calculated values, radio communications with the space stations were disrupted. These same phenomena were also observed by the space vehicle, "Mariner-2".



Flight trajectories of the Soviet robot space stations to Venus: 1 - the launch of "Venus-2" on February 12, 1965; 2 - the launch of "Venus-3" on February 16, 1965; 3 - the flight of "Venus-3" on March 1, 1966; 4 - the launch of "Venus-4" on June 12, 1967; 5 - the arrival of "Venus-4" on October 18, 1967; 6 - the launch of "Venus-5" on January 5, 1969; 7 - the launch of "Venus-6" on January 12, 1969; 8 - the arrival of "Venus-5" on May 16, 1969; 9 - the arrival of "Venus-6" on May 17, 1969.

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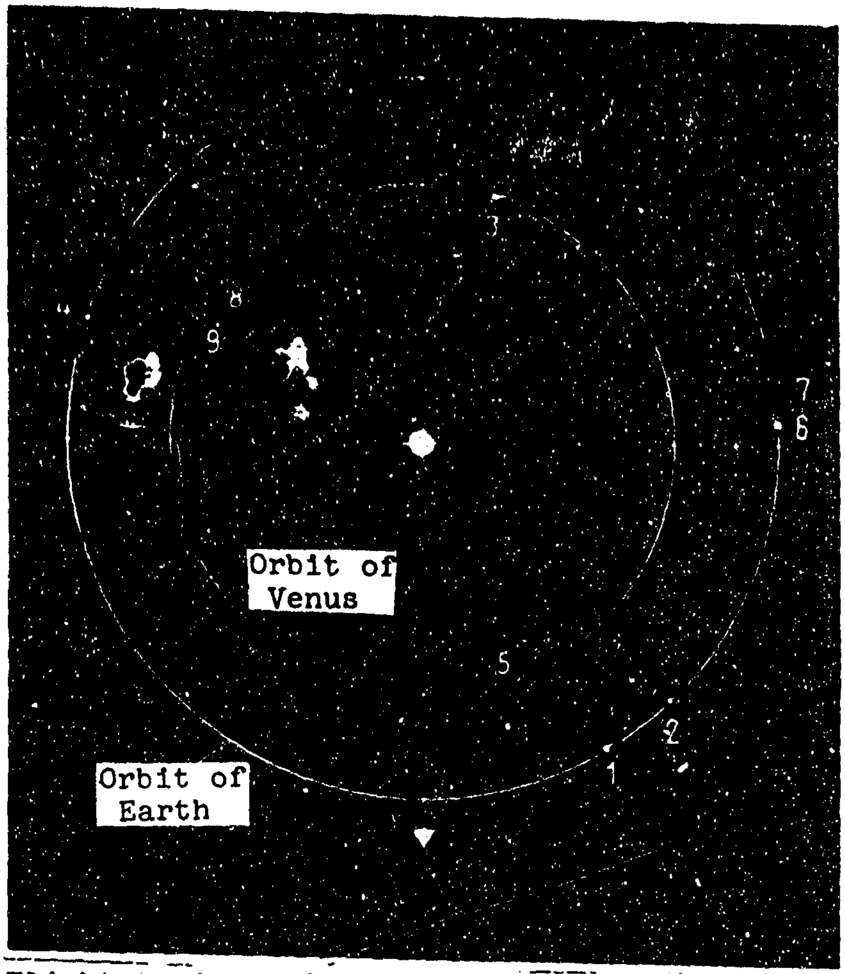

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VENUS REVEALS ITS MYSTERIES

After the launchings of the space stations, "Venus-2" and "Venus-3," a year and a half went by. A new, more favorable astronomical period for launching stations to Venus was approaching.

During this half year, scientists and designers on the basis of the materials obtained from the space stations "Venus-2" and "Venus-3," were developing a new experiment, they were improving components, subassemblies, instruments and systems. In numerous factory shops the conceptions and calculations of engineers and scientists were being converted into practical designs.

In laboratories and on test stands manufactured subassemblies, instruments, components and systems were being subjected to numerous checks and tests. They were subjected to heat and cold, pressure and vacuum, they underwent the effect of insidious solar rays and such overloads on centrifuges that they became several hundred times heavier.

How many sleepless nights were spent on this method of creative construction only the creators of the new station know.

The day of June 12, 1967 arrived. At 0539 the robot space station, "Venus-4" was sent on a remote space path.

The space flight lasted for more than four months. During this time the station entered into communication 114 times with the earth

and transmitted a large volume of information about the processes, which were taking place in outer space, and about the operation of the onboard systems of the station.

On October 18, 1967 at 0734 Moscow time the station, "Venus-4," having covered about 350 million kilometers of its journey, entered into the upper rarefied layers of the atmosphere of the planet. The descent vehicle separated from the space station and traced a fiery arrow across the Venusian sky, braked in the atmosphere at the planet and by parachute completed an almost hour-and-one-half descent, during which a transmission of scientific information about the pressure, temperature, density and the chemical composition of the gases in the atmosphere of Venus was carried out.

For the first time investigations were carried out directly in atmosphere of the mysterious planet, which helped to remove the yashmak [veil], from the face of this celestial beauty.

What were the results of this unique space experiment?

The measurements, carried out during flight along the heliocentric orbit, confirmed much scientific data, obtained in previous interplanetary flights. At the same time these measurements showed that in 1967 the intensity of the flares of solar cosmic rays, characterizing solar activity, increased by hundreds of times in comparison with the years 1964-1965.

The observations in the near-planet phase of the trajectory demonstrated that the high-energy, cosmic-particle flux (up to a distance of 5 thousand kilometers from the surface of Venus) remained constant and was equal to the flux remote from the planet. Below this the magnitude of the flux diminished due to its absorption by the planet. This result attests to the fact that there are no radiation belts near Venus, similar to the terrestrial radiation belts.

The measurements of the magnetic field showed that Venus does

not possess a magnetic field, the dipole moment of which would be more than three ten-thousandth parts of the dipole magnetic moment of the earth. This result refuted the opinion which existed up to that time that near all planets of the solar system there are magnetic fields, similar to the terrestrial magnetic field.

Measurements of solar plasma fluxes near the planet showed that at distances of from 19 to 12-13 thousand kilometers from the surface of the planet there is a considerable increase in the solar plasma fluxes. This is explained by the passage of the station through the front of a shock wave, which is formed during the flowing around of the planet as a solid of the supersonic flux of the solar wind with the magnetic field intruding into it.

The concentration of charged particles in the region of the upper atmosphere of Venus (heights of more than 100 kilometers) does not exceed 1000 particles per cubic centimeter, i.e., two orders less than the maximum concentration of charged particles in the ionosphere of the earth. These data introduced clarity into the disputed question about the ionosphere of Venus and rejected the interpretation that the concentration of charged particles in the ionosphere of Venus is several orders greater than the concentration in the ionosphere of the earth.

It was ascertained that even at a distance of about 10 thousand kilometers from the surface of the planet neutral hydrogen is present in its atmosphere, forming the hydrogen corona of Venus, which contains a thousand times less hydrogen, than the upper atmosphere, forming the hydrogen corona of Venus, which contains a thousand times less hydrogen, than the upper atmosphere of the earth. Atomic oxygen was not detected up to a height of 200 kilometers.

Finally, and mainly, that which with impatience scientists of the whole world had awaited was received. It was known how contradictory were the data about the temperature, pressure, density and the composition of the gases in the atmosphere of Venus. Now

the scientists had in their hands data about the physical characteristics of the atmosphere of the planet, obtained directly from its thickness.

It was established that the basic component of the atmosphere of Venus is carbon dioxide - 90 ± 10 percent. Oxygen was more than 0.4 percent, but less than 1.5 percent, water - not more than 1.6 percent, nitrogen - less than 7 percent.

In the falling of the descent vehicle, in a section with a drop in heights of the order of 28 kilometers the temperature of the atmosphere rose from 25 to 270°C, and the temperature gradient was about 10° per kilometer of height.

The atmospheric pressure during the descent increased from 1 to 18.5 kilogram per square centimeter; the density also changed on the average from $1.2 \cdot 10^3$ to $(16.5\text{-}18.3) \cdot 10^3$ grams per cubic centimeter that on the average exceeds the maximum value of the density of the terrestrial atmosphere by one order.

It is interesting to note that with such high pressures and densities of atmosphere of Venus the boiling of water should occur at a temperature of more than 200°C.

As is evident, conditions on Venus far from paradisiacal and are entirely unsuitable for human existence.

A day after the descent of station "Venus-4" in Venus's atmosphere the American space vehicle "Mariner-5" flew near the planet, and from a distance of more than 4000 kilometers carried out radioscopy of the upper layers of the atmosphere. The data obtained by it could be interpreted only after processing of the results of the investigations, performed by the "Venus-4" station, about the composition of the atmosphere of the planet, and also owing to the utilization of the data, obtained as a result the radar investigations of Venus.

The scientific data, obtained by "Venus-4," helped comprehend and explain many phenomena, which are occurring on this planet.

But many controversial questions still remained unsolved, much data required more precise defining. Some scientists asserted that because of the thick cloud cover and great pressure light does not get to Venus, others held the opposite opinion - solar light, scattering in the clouds, creates uniform lighting of the sky, without shadows, as occurs on earth on a gray cloudy day. A third group considered that the great density of the atmosphere so strongly bends the path of the light rays (the phenomenon of super refraction) that an observer, located on Venus, cannot see the boundaries of its horizon, and sees, figuratively speaking, the back of his own head.

Having the data analyzed which has already become history, obtained from the "Venus-4" station, and having outlined new missions, the scientists and designers decided to prepare for the next astronomical period (it began in January of 1969) launchings of new space vehicles to Venus.

A new hectic period began again for the designers, workers and testers. According to the data of the flight of the "Venus-4" station, necessary changes had to be introduced into the design of new stations. And again there were severe, fault-finding tests of each subassembly, each system, each component with cold, fire, vacuum, and pressure, and with solar radiation, vibrations, and overloads.

And this too is already history. Before us were the interplanetary robot stations the 1968 model - the twin-sisters, "Venus-5" and "Venus-6" created by the genius of the Soviet people, which would be sent off on a distant interplanetary voyage.

In their snow-white attire - heat-insulation shields - with their solar battery panels and antennas folded, with their black, blash-protective screens each of them is reminiscent of a huge butterfly chrysalis.

The factory tests have been completed. Now the space stations and the rocket-carriers affectionately named by the designers "ponies," are destined for the distant journey to the spaceport.

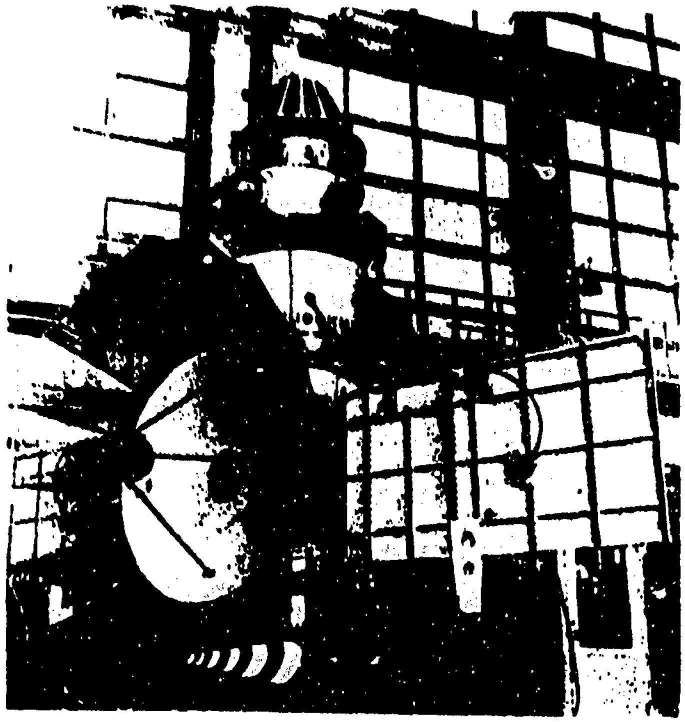
Only there, in the bright assembly hanger, after a whole series of tests and checks, do the space station and the rocket-carrier meet for the first time, in order to be joined together and placed on a launch pad on a neighboring, fire-breathing team of jet engines to be launched into the remoteness of outer space and there to separate from each other forever.

And though we are now not very astonished, reading in the newspapers about the launchings of satellites of the "Cosmos" series, the "Molniya-1" remote space communication satellites, the meterological satellites of the "Meteor" system, the multiton "Proton" scientific laboratories, the automatic space stations, going to the Moon and Venus on their own space missions, we should not forget that each launching of a rocket with a space vehicle onboard is the result of the selfless work of thousands of specialists. Each launching is a joyful and anxious holiday for all, who participated in the creation of a new space vehicle. This is the day of its birth.

The day of the launching of the "Venus-5" and "Venus-6" space stations was drawing near.

The launching of two automatic space stations of the same type had the purpose of receiving practically simultaneous measurements of the parameters of the Venusian atmosphere in two different regions of the planet. This attached a new quality to the space experiment of investigating the atmosphere of Venus.

The astronomical clock strictly determined the month, days, hours, minutes and seconds, when the earth would the most advantageous position for the launch.



In the assembly shop.

The day of January 6, 1969 arrived. It was 0938 at the spaceport. The last seconds before the launch were running out. The people were tense with complete concentrated attention at the command point, the observation points, at the remote space communication center as well as at the coordination-computing center. Briefly, the following command words sound over the loudspeakers and in the headphones: "Drainage activated,"* "First broach,"** Second broach,"*** [Translator's note: Terms with asterisks (*,**,***) not verified. Literal translation of Russian is (*) key on drainage, (**) First broach, (***) Second broach - last two may deal with tapping of tanks or another source said they may be concerned with activating telemetering systems.], "Ignition," "Umbilical release," "Lift off!".

The thunder-like peals assault the earth. The base of the rocket is hidden in clouds of smoke and tongues of flames. The body of the rocket writhes, lifts off the pad, at first very slowly, and then

ever faster and faster it rushes upwards, carrying with it incandescent pillars of flames, a trail of smoke and the shattering roar of the jet engines with a force of hundreds of thousands of horse power.

After several tens of seconds have elapsed, the clouds of smoke and dust of the launch have still not dispersed, and only a glittering point and a weak rumble, being borned from the celestial height, attest to the event which has occurred. But over the loudspeaker a calm voice is again heard: "30 seconds, the flight is normal," "100 seconds, the flight is normal," "The first stage has separated - the flight is normal," "The last stage with the automatic space station has gone into earth orbit - the flight is normal," "The parameters of the orbit are...".

On a luminous map in the hall of the coordination-computing center a beam traces the path of the rocket above the terrestrial surface in the form of an enormous sine curve.

And then when the shining point is moving over the Atlantic Ocean in the region of the Gulf of Guinea, the voice of an operator reports: "The position of the rocket is normal," "The time of the second launch is approaching," "The squibs (cartridge igniters) have operated," "Ignition," "Launch," "The last stage engine has operated the calculated time," "Separation has occured," "The remote space communication center is receiving of telemetric information from onboard the space station and trajectory measurements are being carried out," "The antennas and solar battery panels are deployed," "The pressure and temperature in the space station compartments, the solar battery current is normal," "The communication with the space station is stable," "The space station has gone into the flight trajectory toward Venus, close to the calculated trajectory!!!".

Immediately the whole hall was filled with noise. Everybody stood up and began talking. There were excited and joyful faces. There were congratulations. We also congratulate these great workers, these people enraptured with their formidable victory.

Exactly five days later they launched the "Venus-6" space station.

And before there were about four months of flight of the space stations along the perilous paths of outer space to their target - Venus. There still remained many anxious days and nights for their creators.

Now the power over these space stations was in the hands of the radar operators and controllers. They with the help of the automatic radio facilities, and control instruments, mounted onboard the stations as well as on the earth, they will conduct remote "radio conversations" with them. They will learn in this manner, how the instruments and systems of the stations are operating, what the temperature conditions are and what the pressure is in its compartments. They will carry out trajectory measurements together with ballistics, to determine, along what path in outer space they are accomplishing their journey.

Operating at full power the electronic-computers of the coordination-computing center, will translate the voice of the space stations' radio signals into columns of figures and graphs intelligible to the specialists.

On the luminous panel of the coordination-computing center neon fights in generally understandable form light up the values of various parameters, characterizing the operation of the equipment and of the systems of the space stations, and also their flight time from the beginning of the launch.

While the stations are accomplishing their four month flight to Venus, we will become acquainted with their equipment.

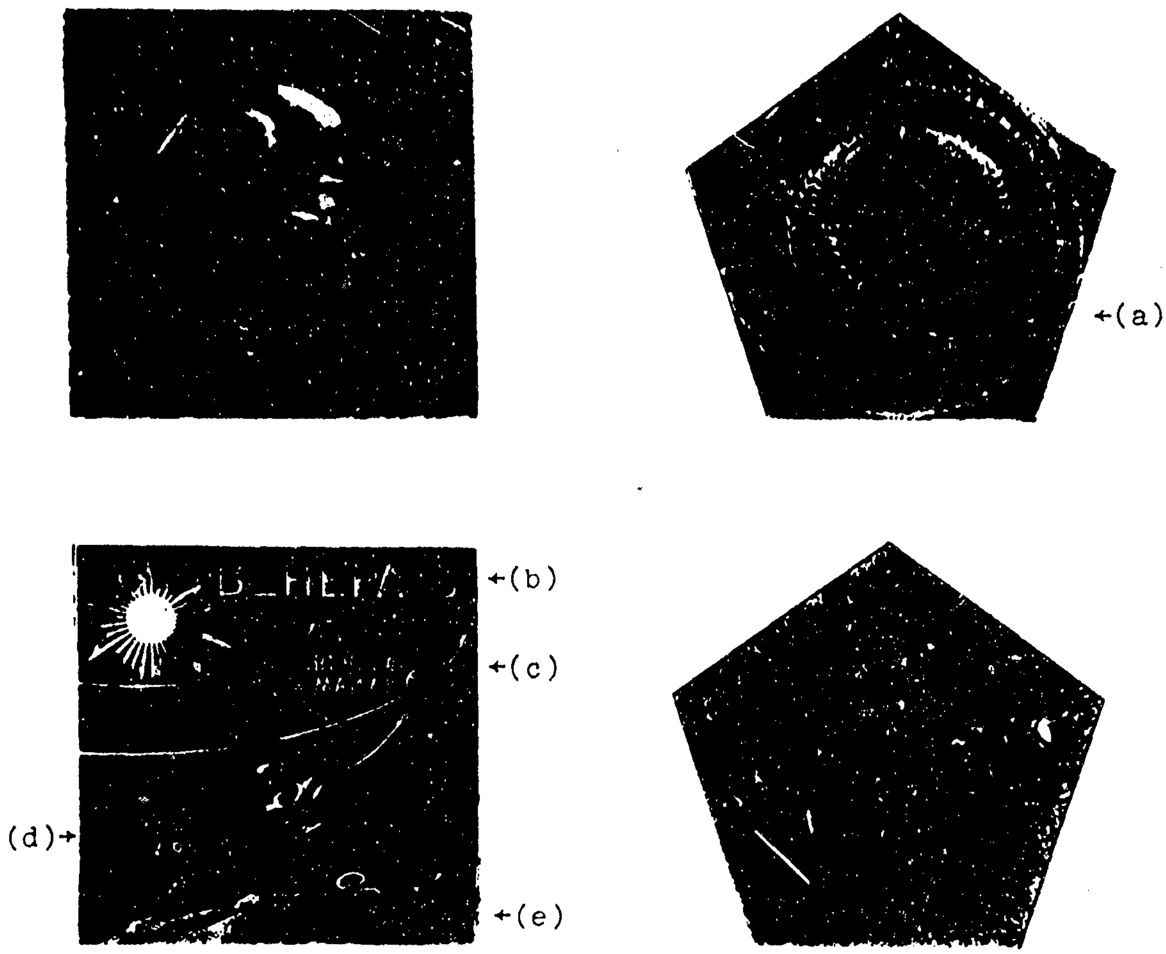
As you remember, the stations were sent on their flight wrapped up in their snow-white attire - heat insulation, the purpose of which together with the thermal control system was to ensure in the

hermetic compartments and in the space station housings the temperature conditions assigned by the flight program.

Let us free the "Venus-5," space station at least for a while from its space "fur-coat," let us activate the mechanisms, which control the deployment of the solar battery panels and the antennas. A miracle takes place right before our eyes: our "chrysalis" is transformed into an exquisite fantastic butterfly with a black and white body. You are struck by its delicateness and the strict engineering rationality of its shapes. It is similar and disimilar to its predecessors - "Venus-2," "Venus-3" and "Venus-4." It took from them everything that passed the test of outer space, discarding or altering those design elements and of systems, the expediency and the reliability of which were confirmed in the flights of its predecessors.

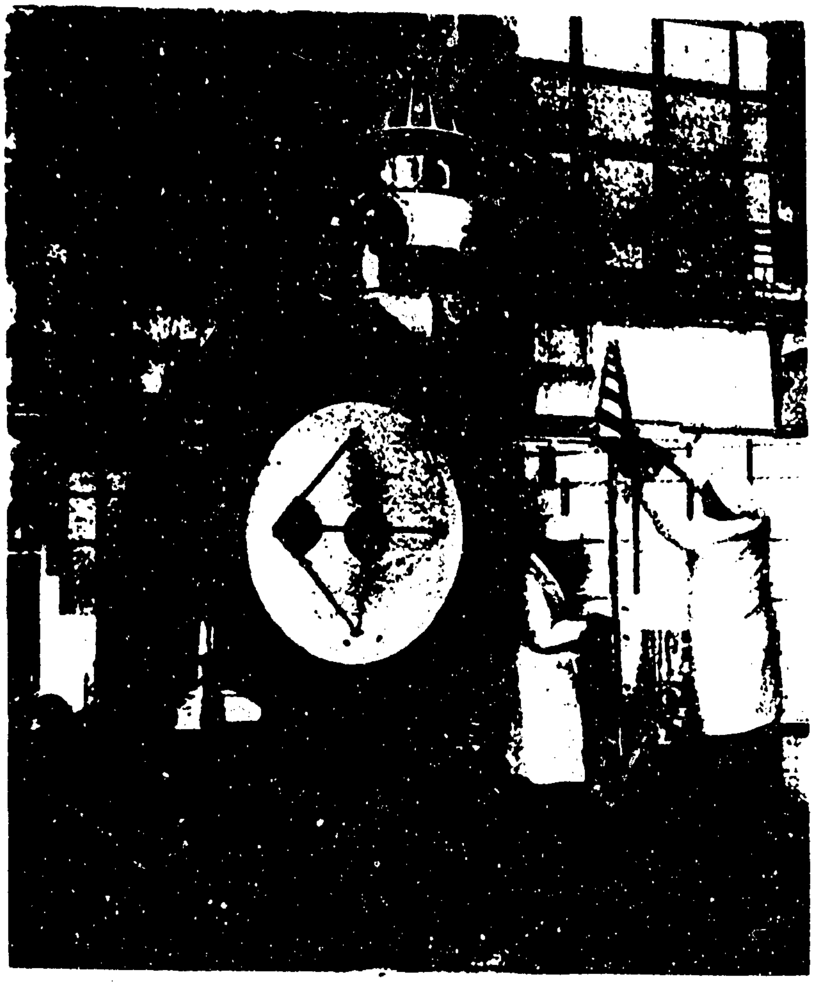
The main supporting design element of the station is the cylindrical orbital compartment, to which on one side the engine correcting device is mounted and on the opposite side, on special fasteners, - the descent vehicle - a scientific laboratory, intended for carrying out investigations in the Venusian atmosphere. To the orbital compartment the solar battery panels are attached, which in flight, being constantly oriented to the sun, convert light energy into electrical energy and charge the buffer batteries - chemical sources of electric energy - of the orbital compartment and the descent vehicle. On the solar battery panels two conical helical antennas of the onboard radio complex are mounted.

On the orbital compartment there are mounted: the parabolical (pencil-beam) antenna of the radio complex, the base of which performs the role of radiator-heat exchanger of the thermal regulation system; optical sensors of the astronomical orientation system; actuating elements of the astronomical orientation system - microengines, operating on compressed gas; compressed gas receptacles; sensors of scientific instruments, which ensure the carrying out of the scientific investigations on the flight path and in circumplanetary space.

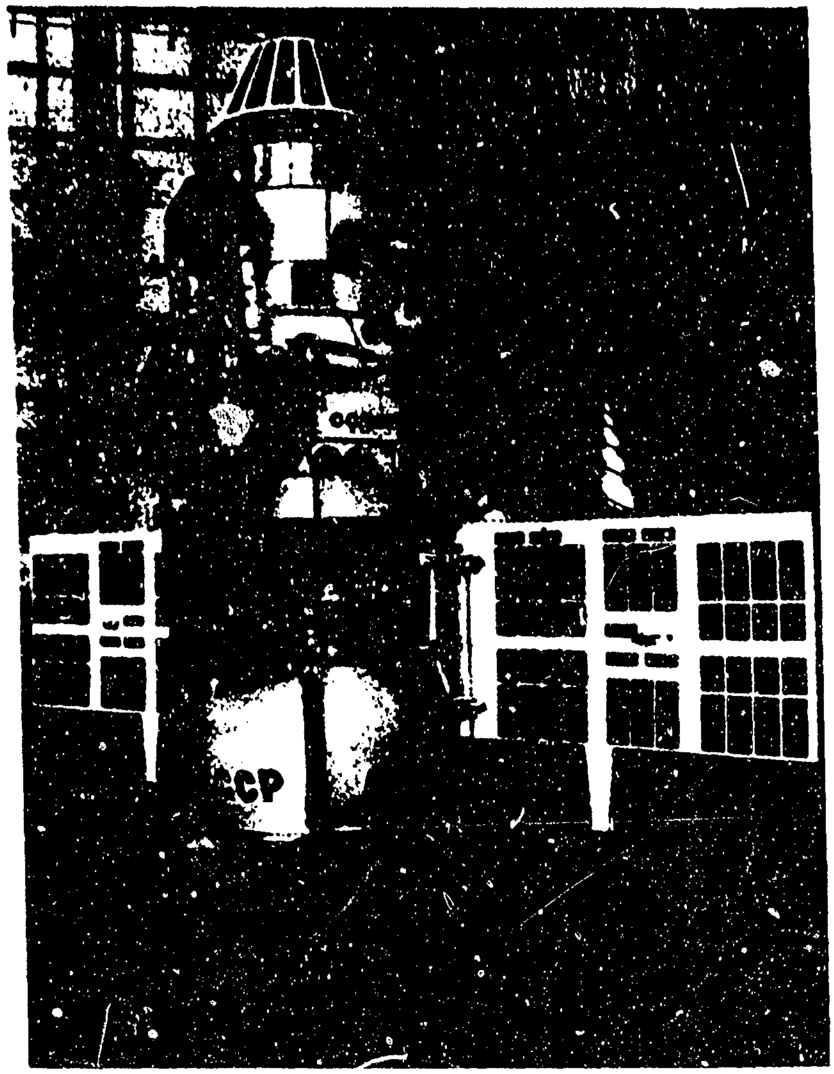


The message bags of the "Venus-5" space station.

KEY: (a) Union of Soviet Socialist Republic; (b) Venus-5; (c) Venus, May 69; (d) The Earth, Jan. 69; (e) The USSR.



The "Venus-6" automatic station.



The "Venus-5" space station.

Before launch to reduce the dimensions the solar battery panels and the antennas are folded up, and upon completion of operation of the last stage of the rocket-carrier the nose fairing is jettisoned and all the indicated design elements occupy the working position.

The orbital compartment is a hermetic container, designed to operate under space conditions. In the container are placed the equipment, instruments and systems of the station, servicing it on the Earth-Venus flight path. Included among them are: the onboard radio complex; the thermal regulation and control system; the units of the astronomical orientation system; the scientific equipment; the power supply system; the chemical sources of current.

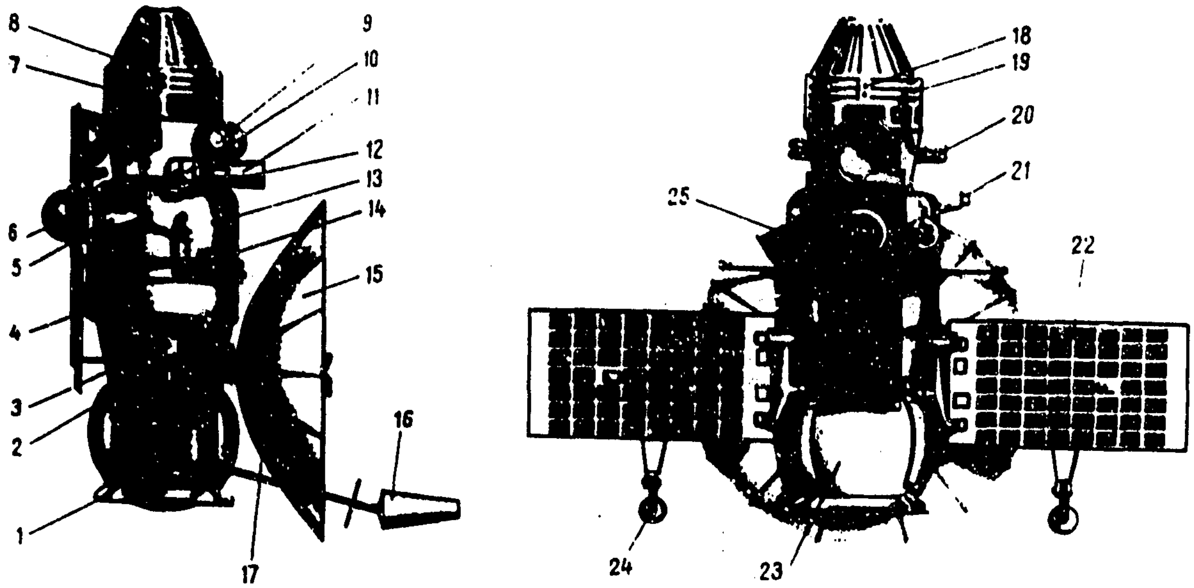
As was already mentioned, in developing all these instruments and systems special attention was focussed on ensuring high operatival reliability of the whole complex. Apart from the severe tests, to which all the instruments and systems of the space station were subjected, in assemblages of instruments, equipment and systems backup-redundancy is broadly employed, and in certain cases, in especially critical sites, double backup of units, instruments, and frequently of whole systems.

Each of the enumerated systems of a space station performs in flight strictly defined functions, specified for it by the flight program.

Let us examine the operation of one of the basic systems of a space station - the complex of the orbital compartment.

The radio complex consists of two parts - a receiver and a transmitter, which operate in the several regimes, ensuring: control of the instruments, equipment and systems of the space station (command radio link); telemetering measurements (direct transmission of parameter values, characterizing the operation of all systems of the space station in communication transmissions); recording on an electronic memory device, the reproduction and transmission to earth

of the scientific information and data about the operation of the astronomical orientation system accumulated between communication transmissions; the carrying out together with the ground radio complex of trajectory measurements - the determination of the location of the space station with respect to angular coordinates, velocities and distance.



The arrangement of the "Venus-5" robot space station: 1 - ring fastening the space station to the accelerating unit; 2 - automatic control unit to the microengines of the orientation system; 3 - high pressure tanks of the orientation system; 4 - orbital compartment drier; 5, 6, 10, 12 - astronomical orientation system sensors; 7 - collectors of the gas orientation system; 8 - engine correcting device (ECD); 9 - ECD tanks; 11 - the orientation sensor cylindrical shield; 13 - orbital compartment; 14 - ultra-violet photometer; 15 - pencil beam parabolic antenna; 16, 24 - narrow-beam antennas; 17 - thermal regulation system radiator; 18, 19, 20 - orientation system microengines; 21 - cosmic particle counter; 22 - solar battery panels; 23 - descent vehicle; 25 - astronomical orientation system sensor flash-protective screen.

The reception of control command-signals, the transmission of information from onboard the space station to earth and the carrying out of trajectory measurements on the Earth-Venus flight path are accomplished via one of the three antennas, mounted onboard the space station: the pencil-beam parabolic antennas with a diameter of 2330 millimeters or one of the two omnidirectional antennas

depending on the tasks of the communication transmission and the distance of the space station from the earth.

In the make-up of a radio complex for solving assigned tasks there are included: two complete receiver sets, of two complete transmitter sets, decoders, automatic and signal forming units, modulating devices, master generators, telemetering commutators and a whole series of other units and devices. The control of the operation of this complex radio complex is carried out either automatically from an onboard time-program device, or by radio commands from the earth.

Each radio communication session has its own specific purpose and it must be carried out strictly in accordance with the established program, since all commands are logical linked with each other and the nonfulfillment of one of them can delay the carrying out of a session or cancel it out completely.

Depending upon the purpose the following communication transmissions are carried out:

a terrestrial transmission in which the operation of all the onboard systems is thoroughly checked and trajectory measurements are carried out;

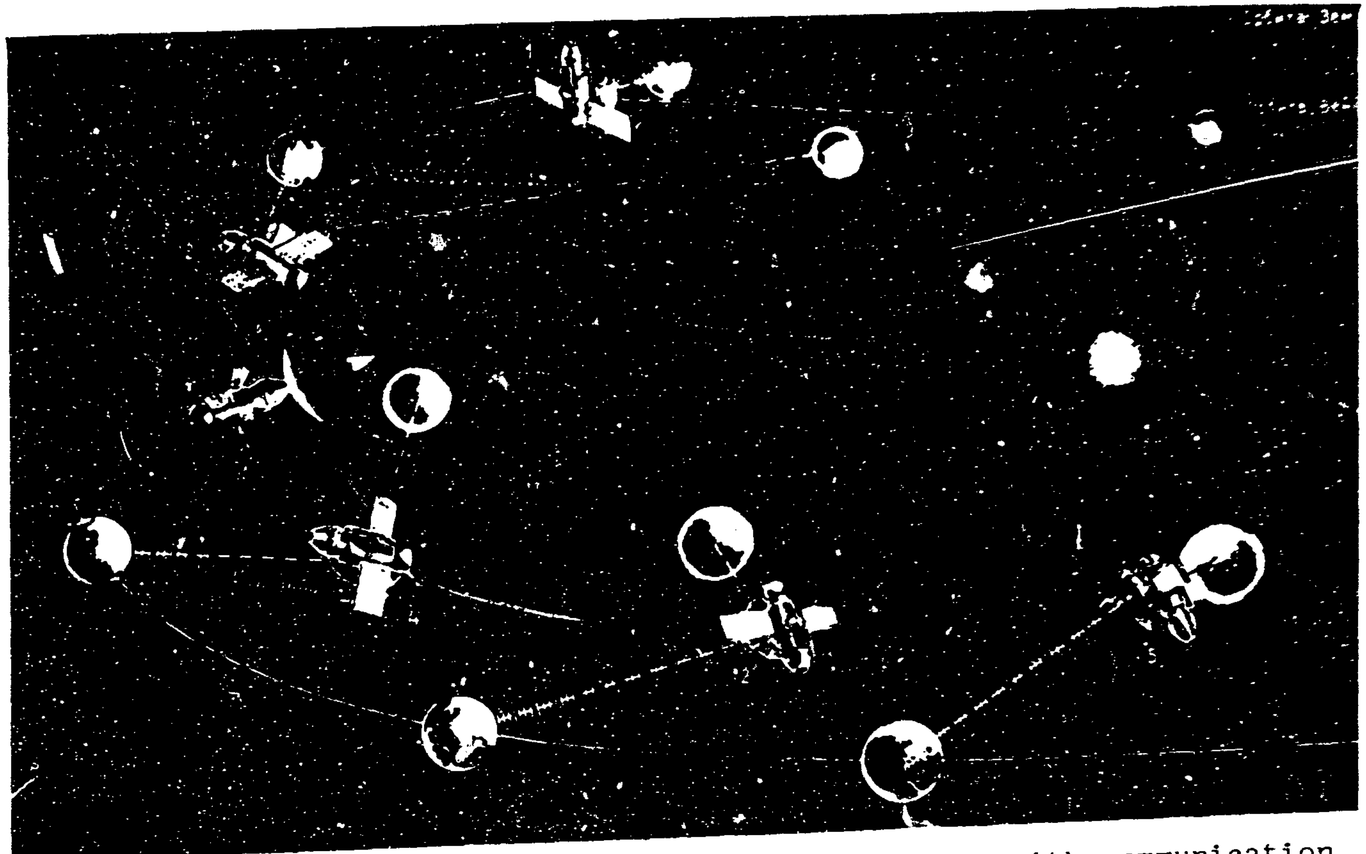
a standard transmission of the telemetering measurements and the transmission of scientific information about the flight trajectory;

a standard transmission of the trajectory measurements about the flight trajectory, in which the distance, the velocity of the space station and its position in space are determined;

a transmission for the astronomical correction of the flight trajectory of the space station;

a near-planetary communication transmission before entry into the Venusian atmosphere.

Orbital compartment.



A diagram of the flight of the "Venus-5" space station with communication transmissions: 1 - terrestrial communication transmission; 2 - communication transmission on a pencil-beam antenna; 3 - astronomical correction transmission; 4 - communication transmission on a narrow-beam antenna; 5 - near-planetary communication transmission.

KEY: (a) Earth orbit; (b) Venus orbit.

In speaking about the operation of the radio complex of a space station, it is necessary to note the difficulty, which space distances introduce into its operation. On the earth we are accustomed to the fact that radio waves, sent from a radio station, reach receivers instantaneously. Communication over interplanetary distances is an entirely different matter - from the command issuance to its performance several minutes elapse. In the concluding stage of a flight from the command transmission until the reception of an answer from onboard the space station time elapses, during which it is possible to calmly do one's daily dozen or to drink a glass of tea with cake. Thus commands from earth are emitted in accordance with those time intervals, which have been defined by the flight program.

Between communication transmissions the radio equipment of a space station is on a duty regime, i.e., only one receiver set and the corresponding electronic equpment, serving the command radio link of space station is switched on. Upon receiving a command from the earth the control devices activate those units of the radio complex, systems and equipment of the space station, which as a result of this command should be put into operation.

In accordance with the established program or upon commands from the earth the activation of sets of receiver-transmission equipment and units of the radio complex occurs.

Thus, in the case of the breakdown of any instrument or element of the system a reserve instrument or reserve system is always ready to replace it.

It is necessary to note that during the whole time of flights of the "Venus-4" and "Venus-6" space stations it was not necessary to resort to these measures. The equipment performed faultlessly.

In speaking about the operation of a space radio complex, it is also necessary to remember the other great difficulties, which extremely complicate radio communication. Among these are first of

all radio noises, coming from the sun, other stars, constellations and nebulae. And radio signals from a space station at great distances weaken and become indistinguishable from noise. The signals, as radio operators say, must be extracted from these noises, filtered out, amplified and converted into a clear signal which is recorded on a magnetic tape and on computer tapes in the form of columns of figures and graphs.

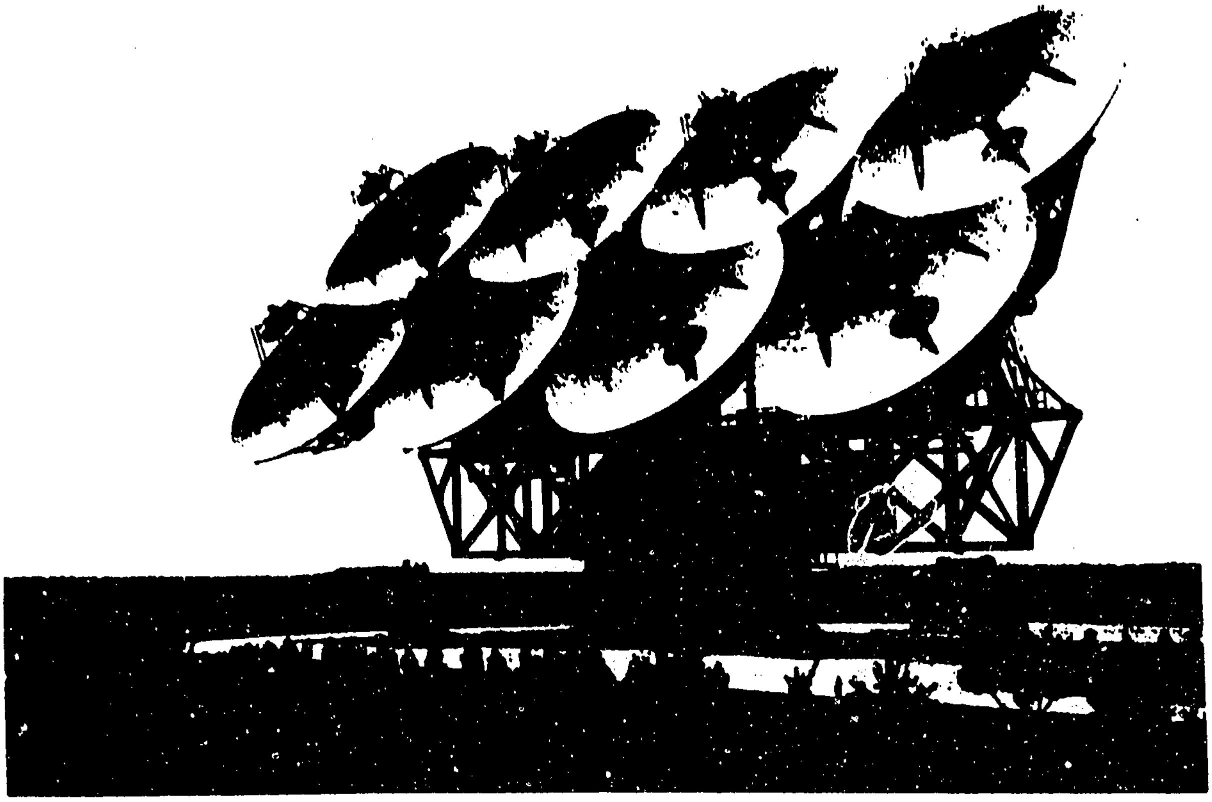
Another factor, complicating radio communication, is the great increase in the velocity of the space station during its approach to the planet, when the most valuable scientific information is being transmitted. And in accordance with the so called Doppler effect there is a change in the length of the radio wave in connection with the considerable change in the velocity of the transmitter relative to the ground receiver.

The engineers and operators in The Remote Space Communication Center coped brilliantly with those difficult problems, they ensure the reliable operation of the receiving antennas and all the other equipment.

When you see these eight 16-meter dish antennas assembled on one framework, it seems improbable that this machine with the height of a ten-story building can with an accuracy of a few angular minutes track the flight of a space station, move on its own supports with surprising ease, carrying out the will of the operators.

For normal operation the onboard radio complex and all the other systems of a space station must be provided with electric power.

In the make-up of the power supply system of the space station, apart from the solar batteries and the semiconductor converters, which occupy an area of 2.5 square meters, and the chemical storage batteries, there is also included a unit controlling of the power supply sources, an ampere-hour meter and a system of regulation.



The antennas of The Remote Space Communication Center.

The indicated devices ensure the operation of the systems of a space station in a range of from ten up to several hundreds of watts of required power.

In connection with this the light flux from the Sun with the approach of the space station to Venus increases according to the law of the square of the distance, and consequently, the amount of electric power, being manufactured by the solar batteries also increases, which can lead to the overcharging of the chemical sources of current, in the flight program the appropriate shiftings of sections of the solar battery panels are provided for, making it possible to maintain the current magnitude within the assigned limits.

One of the basic vitally important systems of a space station, on the normal operation of which depends the successful operation of the other systems, in the system of thermal regulation. In the

beginning of the flight it should protect the space station from freezing, and during the spproach to Venus - from the all-incinerating rays of the sun. These tasks are diametrically opposed.

The necessary thermal regime of the design elements and of the onboard system is ensured by a combination of passive and active methods of thermal regulation.

The passive system of thermal regulation is thermal insulation and the appropriate color coatings; the thermal insulation does not make it possible to sharply change the thermal flux either to the minus or to the plus side, and the color of the surface ensures the necessary thermal radiation of surpluses of heat of the designs of the space station or on the other hand its acquisition, where the temperature on the design elements should not fall below an assigned limit.

The active method is realized by an air system of thermal regulation of the hermetic compartments by fan ventilation, by a heat exchanger-radiator, by temperature sensors, by a system of regulation, by ducts and by valves.

On the operation of this system the highest requirements were imposed during the test stand development on earth.

But not all the regimes of its operation can be checked by tests under terrestrial conditions. For example, it is impossible to reproduce the condition of weightlessness for a prolonged period of time, during which the pattern of heat distribution in the compartments of the space station radically changes, because in this case due to thermal exchange convection is wholly and completely eliminated. Thus in the thermal regulation system, apart from the fan, which provides exchange of air between the compartments of the space station and the heat exchanger, at sites with the maximum heat emission a number ventilation fans is placed, which operate when a heat-emitting instrument or system is operating.

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On the operation of this system the highest requirements were imposed during the test stand development on earth.

But not all the regimes of its operation can be checked by tests under terrestrial conditions. For example, it is impossible to reproduce the condition of weightlessness for a prolonged period of time, during which the pattern of heat distribution in the compartments of the space station radically changes, because in this case due to thermal exchange convection is wholly and completely eliminated. Thus in the thermal regulation system, apart from the fan, which provides exchange of air between the compartments of the space station and the heat exchanger, at sites with the maximum heat emission a number ventilation fans is placed, which operate when a heat-emitting instrument or system is operating.

The thermal regulation system operates according to the following cycle. During the course of the flight the main heat source in the compartments of the space station is the operating equipment of the space station. There is a gradual increase in the temperature in the compartments. On reaching the upper response limit upon command from the temperature-sensitive element a valve is opened, air from the compartment enters the heat exchanger (the cold circuit), imparts heat to its walls, which is radiated into outer space. The air itself is cooled and again enters the compartment of the station, where it removes heat from the heated instruments and again returns to the heat exchanger. This continues until the temperature in the compartments drop to the lower response limit; then the valve is closed and the entire cycle with heat accumulation is repeated anew.

In the way the thermal regulation system operates for approximately half of the flight time. And then an already substantial influence of heat balance of the space station begins to be rendered by the radiant energy of the Sun. Thus, a regime of constant activation of the cold circuit is provided for, yielding the necessary thermal condition in the compartments of the space during the second half of the journey.

It all seems very simple. But this simplicity has been achieved only due to the experience of the flights of the previous space stations, the large number of ground experiments and the meticulous work of the designers and engineers.

As a result the thermal regulation system performed brilliantly in flight; nowhere in the compartments of the space station did the temperature exceed 20-25°C. The most favorable condition for the operation of all the instruments and systems of the space station was achieved.

The position of the ship in oceanic space is determined by a navigator with the aid of celestial luminaries. By carrying out calculations, he determines the position of the ship and, having calculated the deviation of the ship from the assigned course, gives

a command to the helmsman to change the course, and to the machine section - the command to change the velocity of the ship to ensure its timely arrival at the port of destination.

Thus our messengers, the space stations "Venus-5" and "Venus-6", should arrive accurately at the point of destination - the planet Venus - at the specified time, and the moment of their arrival could be fixed by the remote space communication point, located close to the territory of the Soviet Union.

The role of the navigator of distant sailing and of the power device on our space stations was played by the astronomical orientation system and the engine correcting device. How did they manage to cope with this task?

There are three basic conditions of operation of the astronimical orientation system.

The first condition - the so named condition of constant solar orientation. Under this condition the solar battery panels are always directed toward the Sun and they provide the charging of the chemical sources of current - the storage batteries. If it were not for this condition the space station after a few days would go out of commission.

This condition is ensured with the aid of an optical-electronic constant solar orientation sensor. If the Sun is located in the center of the field of vision of the sensor, then the error signal is equal to zero and no controlling commands are sent to the actuating elements (microengines) of the control system.

If the Sun leaves the field of vision of the sensor, that unbalance occurs in the electronic circuits, the control system activates the controlling microengine, which imports the necessary pulse to the space station and returns it to the original position.

Taking into account that the condition of the orientation of

the solar battery panels is vitally important for the operation of all systems of the space station, it is backed up by a condition of gyroscopic twisting of the space station around an axis, perpendicular to the surface of the solar battery panels.

First with the aid of another solar sensor the panels are oriented to the Sun.

The second condition - the condition of orientating parabolic antenna toward the Earth. Under this condition, when the whole power of the onboard transmitter is most effectively being used, because the radio signals are focused by the antenna in a narrow beam and directed to the Earth, and are not scattered in all directions, the possibility exists to carry out the transmission of the maximum amount of information with maximum signal value. This is especially important, when the space station is tens of millions of kilometers distant from the Earth.

For carrying out this condition in the astronomical orientation system there are two mobile "tubes" - one with a solar, the other with a terrestrial sensor.

With respect to the trajectory measurements, carried out with the aid of the onboard the ground radio complexes, the values of two angles are calculated - the angle between the longitudinal axis of the space station and the direction to the Sun and the Sun-space station-Earth angle.

The values of these angles are transmitted to the memory unit of the control system over the radio link. Upon command from the Earth solar and terrestrial "tubes" are set (turned) at these angles, after which the orientation operation to the Earth begins.

In this case with the aid of the microengines of the control system the solar sensor is turned in the direction of the Sun, then the matching of the longitudinal axis of the space station with the

direction to the Sun occurs, after which the space station turns around its longitudinal axis until it locks on the Earth with its terrestrial sensor; and the parabolic antenna is directed to the Earth with an accuracy of a few angular minutes and begins radio transmission with the Earth begins.

Upon completion of this transmission the space station with the aid the same microengines, the control system and the solar sensors again transfers to the condition of constant solar orientation.

The third condition - the condition of correcting the trajectory.

As was already mentioned, during the insertion of the stations on a flight trajectory to Venus and during the flights there act on them: the thrust force of the engine system, pulses from the motors of the stabilization system, the the gravitational fields of the Earth, Sun, Moon and planets and a whole series of other factors. The magnitudes of the acting forces are not always exactly known and not all of them can be taken into account. As a result of this the true flight trajectory of the space stations differs from the calculated trajectory. Obviously, it is necessary to determine the magnitude of this divergence and by appropriate means to correct the flight trajectories of the space stations. From the data of the trajectory measurements this divergence was clarified, the magnitude and the direction of the correcting pulses and the angle values were determined, to which the space stations must first be spread in space before the correction.

Over the radio link the values of the angle magnitudes, the time of operation of the engine correcting device were transmitted in the form of arrangements (digital code) to the electronic memory units of the space station.

A very important condition of the flights of the space had arrived - the correction condition.

In this condition high orientation accuracy and high operational accuracy of the engine correcting devices are necessary.

The reference luminaries [heavenly bodies] in carrying out this operation were the Sun and the star Sirius. The orientation of the space stations was carried out relative to the direction to these luminaries; for this the values of the angles of orientation, put in the memory of the space stations were calculated.

During the correction operations, both stations were oriented in such a way that during the operation of the correcting engine device it was possible to eliminate the error between the trajectories - true and calculated, and to ensure the arrival of the space stations at the assigned regions of Venus and their arrival at the calculated time - about 0900 Moscow time on May 16, 1969 for the "Venus-5" station and May 17, 1969 for the "Venus-6" station, when Venus was located in the zone of radio visibility of the antennas of the Remote Space Radio Communication Center.

The region of entry into the atmosphere of Venus was selected taking into account the following considerations. Since the maximum directional diagram of the transmitting antenna of the descent vehicle coincides with its longitudinal axis, during descent by parachute the directional diagram will coincide with the local vertical. If during the descent the direction of the local vertical coincides with the Venus-Earth direction, then, obviously, the signal being received on Earth, will be the strongest. Therefore most favorable region of entry of the space station into the atmosphere of Venus rests in the center of the disc of the planet visible from the Earth.

Under these conditions the approach to Venus is always carried out on the dark side of the planet and the point of entry into the atmosphere is located on the dark side of Venus. For the space stations "Venus-5" and "Venus-6" the point of entry into the atmosphere of Venus was located on the night side of the planet at

a distance of 2700 kilometers from the line of the terminator, i. e., the boundary of day and night.

The entry of the vehicle into the atmosphere of the planet must be carried out at a definite angle. With so dense an atmosphere as is observed on Venus, the magnitude of entry angle of the vehicle into the atmosphere is large. Too steep an entry leads to a sharp increase in the overloads and considerable heating of the descent vehicle during aerodynamic breaking in the atmosphere of the planet which can lead to its destruction. At small angles of entry, i.e., a slanting entry, the "non-capture" of the space station by the atmosphere of the planet is possible. Therefore a certain permissible range of angles of entry into the atmosphere exists.

For the stations "Venus-5" and "Venus-6" the angles of entry into the atmosphere of the planet were 62-65 degrees relative to the local horizon, and the velocity of entry - 11.18 kilometers per second.

For bringing about orientation of the space stations very small moments of force are necessary, created by the mircoengines. The magnitude of the moments, which appear during the operation of the correcting motor, exceeds by several orders of magnitude the magnitude of the moments from the microengines, therefore after completion of the process of orientating of the space station with respect to the Sun and Star Sirius before activating the correcting motor the gyroscopic system of stabilization, controlling the operation of the stabilization motors and ensuring stabilization of the space station goes into operation before completion of the operation of the correcting motor.

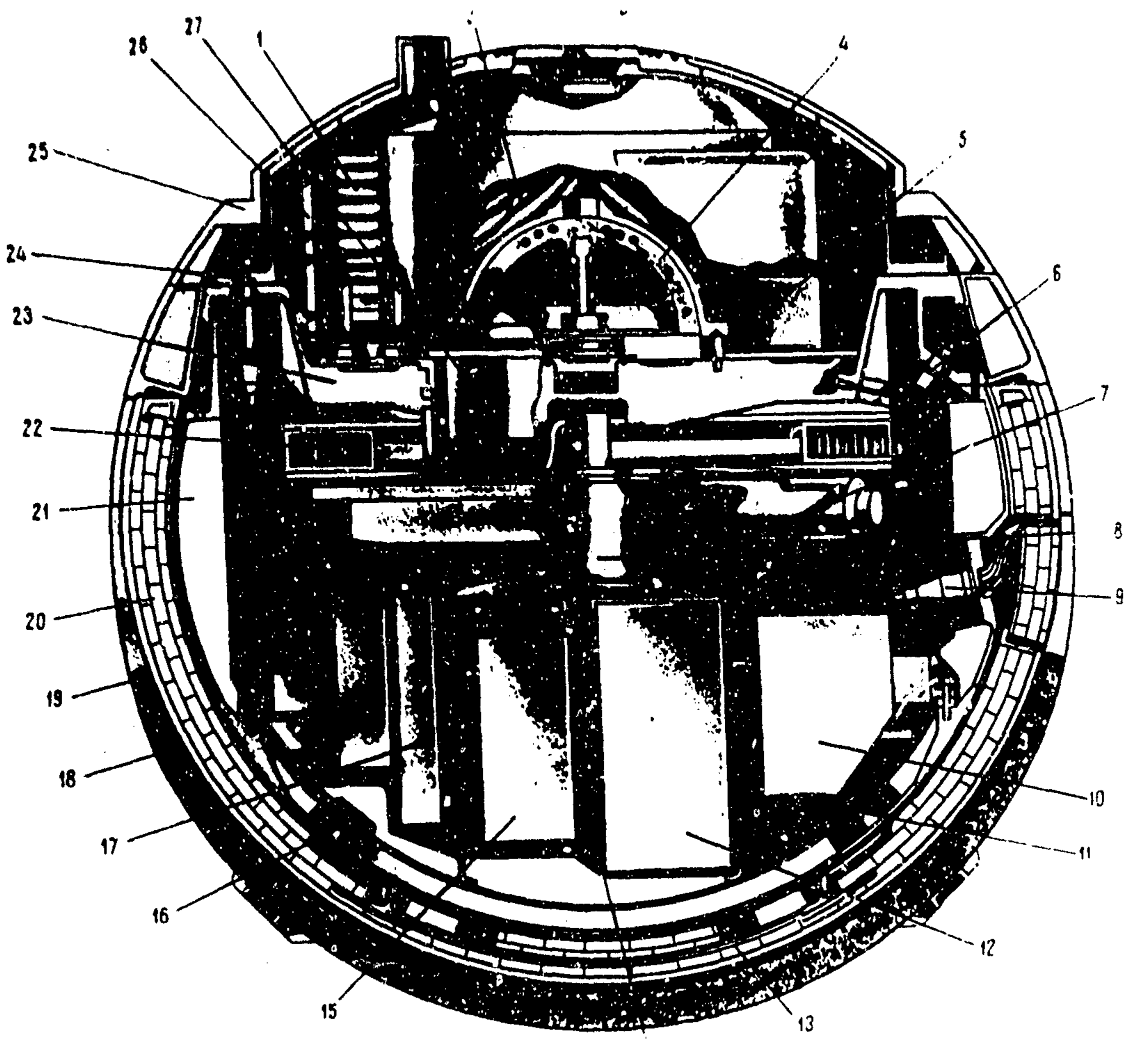
On March 14 and 16, 1969, when the space stations "Venus-5" and "Venus-6" were located at distances respectively of 15.5 and 15.7 million kilometers from the Earth, at a strictly calculated time, on command from the on-board program-time devices, the correcting motors were activated, which, having operated for the assigned

time, put the space stations on trajectories, ensuring the arrival of the stations at the assigned regions of the planet Venus.

The trajectory measurements, carried out after the correction operation, confirmed the correctness of the ballistic calculations and the high accuracy of their realization. The moment of entry of the stations into the atmosphere of Venus was predicted with an accuracy of a few seconds, and the coordinates of the region of entry - to within an accuracy of 200 kilometers. Inasmuch as the first correction was carried out with high accuracy, the second correction was not required, although it was provided for the flight program.

The descent vehicle [general view].

The designers, engineers, ballisticians, operators had arrived at a new stage of operation. Near-planetary communication transmissions and the carrying out of investigations during the fall of a descent vehicle into the atmosphere of Venus had been accomplished.



Arrangement of a descent vehicle: 1 - braking parachute; 2 - main parachute; 3 - pyro-ejector cover; 4 - transmitting antenna; 5 - density gauge sensor; 6 - grooved charge valve, 7 - drier; 8 - thermal control system fan; 9 - hermo-outlet; 10 - commutation unit; 11, 16 - acceleration sensors; 12 - transmitter, 13 - mechanical oscillation damper; 14 - power supply unit; 15 - onboard transmitter; 17 - program-time device 18, 19, 20 - design elements of the external heat shield, 21 - internal heat insulation; 22 - thermal control system; 23 - descent vehicle housing; 24 - pyro-ejector; 25 - parachute section cover; 26 - radio altimeter antenna; 27 - gas analyzer.

It was still necessary to check the equipment of the orbital compartments and the descent vehicles of the space stations and the whole ground command-receiving part of the radio complex one more time.

What is the descent vehicle?

The descent vehicle in shape is close to being a sphere, with a diameter of about one meter, its weight is 405 kilograms. The external surface of the sphere, especially its lower part, is equipped with a thick heat shield, retarding heat influx from the surface of the sphere into the hermetic container during the fall of the descent vehicle in the dense layers of the atmosphere. The descent vehicle actually enters into the atmosphere at second space velocity [escape velocity] - about 11 kilometers per second, - and after the shock wave, which appears in front of the vehicle, as a result of aerodynamic breaking the temperature exceeds 10,000°C. At this temperature the surface of the descent vehicle does not burn, but simply volatilizes.

Furthermore, during the breaking huge overloads arise, as a result of which each element of the descent vehicle weighs approximately 450 times more, than it weighed on Earth under normal conditions.

Just these two circumstances show, what difficulties confronted the creators of the descent vehicle.

The descent vehicles consists of two compartments isolated from each other: the upper - the parachute compartment and the lower - the instrument compartment.

In the parachute compartment a two-stage parachute system is situated, consisting of a braking and a main parachute. The fabric of these parachutes retains the required mechanical strength at temperatures above 500°C.

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In this there are also situated the transmitting antenna of the radio complex, the scientific equipment sensors and the radio altimeter antenna. The parachute compartment is equipped with a jettisonable hermetic cover.

In the instrument section of the descent vehicle there are located: the onboard radio transmitter, the program-time device, the automatic units, the telemetering system, the radio altimeter, the storage battery, the thermal control system and the scientific equipment.

Parachute compartment of the descent vehicle.

To increase the stability of the descent vehicle in the atmosphere of Venus and to decrease the amplitude of its oscillations a special mechanical damper is mounted in its lower section.

In the descent vehicles there were located the space log books of the stations - message bags with a bas-relief of Vladimir Il'ich Lenin and representation of the Emblem of the Soviet Union.

It is necessary to note that the descent vehicles of the "Venus-5" and Venus-6" stations were subjected to design changes in comparison to the descent vehicle of the "Venus-4" station.

Actually, the descent vehicle of the "Venus-4" station was built when the range of the assumed pressures and temperatures of the surface of Venus varied from one to hundreds of atmospheres and from -30°C to +400°C, thus it was built for a certain mean model of the atmosphere of Venus and could withstand a pressure of about 20 atmospheres and carry out measurements from a height of approximately 30 kilometers after the opening of the main parachute.

The values of the parameters of the atmosphere, obtained as a result of the preliminary processing of the data from the "Venus-4" station with recording of the radio altimeter, equal to 28 kilometers, and in the deeper layers, coincided well with the value of the covered path during the descent of the vehicle in the atmosphere of the planet from the moment of the obtaining of the height recording to the moment of the cessation of communications. Data obtained in this case agreed well with the height value, calculated from the conditions of the hydrostatic equilibrium of the atmosphere.

This agreement of the results, obtained by various methods, laid the foundation for drawing the conclusion that the measurement of the parameters of the atmosphere was carried out by the descent vehicle of the "Venus-4" station the surface of the planet itself.

As a result of subsequent careful processing of the data, obtained by the sounding of the atmosphere of Venus by the "Venus-4" station, together with the data of the most recent radio-astronomical and radar investigations, and also with the data, obtained from the "Mariner-5" vehicle, scientists expressed the assumption that the values of pressure and temperatures near the surface of the planets were higher than that indicated by the "Venus-4" station. In this case one characteristic in the operation of the radio altimeter of the "Venus-4" station was considered: the indications of the radio altimeter could correspond to two height values, differing from each other by 30-40 kilometers. This phenomenon of ambiguity is peculiar to all radio altimeters with periodic frequency

modulation, and the ignorance of the characteristics of the atmosphere of Venus could lead to the fact that the opening of the parachute and the beginning of the measurements started considerably earlier than the calculated values of height beyond the upper threshold of ambiguity. Therefore considerations were expressed that the measurements, carried out from the descent vehicle of the "Venus-4" station, could cease at a certain height above the surface of the planet, when the external pressure of the atmosphere, having attained a magnitude, greater than the maximum strength of the housing of the descent vehicle, imploded the upper cover of the instrument compartment and led to the breakdown of the operation of the radio complex equipment. Due to this during the subsequent fall of the descent vehicle of the "Venus-4" station no more measurements were carried out.

In preparing for the new experiment it was tempting to so strengthen the housings of the descent vehicles of the "Venus-5 and "Venus-6" stations, so that they could carry out sounding of the atmosphere right down to the surface of the planet, but inasmuch as the strengthening of the housings of the descent vehicles by 5-8 times, as was required by the atmospheric pressure of the surface of Venus, would lead to a drastic weight increase in these vehicles, and as a consequence, to a decrease in the composition of the scientific equipment, it was considered irrational to introduce such serious changes in the design and composition of the scientific equipment of the descent vehicle.

The basic purpose which was outlined by the scientists in launching the "Venus-5" and "Venus-6" stations, consisted in increasing the accuracy of the measurements of the chemical composition and the parameters of the atmosphere and the heights corresponding to them and in increasing the depth of penetration into the atmosphere of Venus.

In connection with this the housings of the descent vehicles of the stations were strengthened in order to withstand an external

pressure of up to 25-27 atmospheres and higher temperatures and overloads in comparison with "Venus-4".

To increase the rate of fall of the descent vehicle in the atmosphere of Venus four times the area of the main chute was reduced, because the parachute of the "Venus-4" station was calculated for smaller values of density of the atmosphere of the planet.

The composition of the scientific equipment of the descent vehicles was also partially changed. A new, more improved radio altimeter was installed, in which the possibility of ambiguity of measurements was completely eliminated.

Entry and Descent in the Atmosphere of Venus

It was early on the morning of May 16, 1969. The pink horizon was covered with mist. The Sun had still not risen, and Venus shone above the horizon in its amazing brilliance.

The morning silence of the Remote Space Communication Center was broken by the sound of a siren, and the automatic equipment slowly activated the two receiving antennas into motion.

The eight eighteen-meter parabolical dishes of each antenna were aimed at remote Venus and, it seems listened to its voice.

But no, they were not listening to Venus now, they were intercepting signals, which were being sent from the "Venus-5" station from a distance of 67 million kilometers from the Earth. The magnitude of the signals, weakened by this cosmic distance, was so small that they were indistinguishable from the radio-noise outer space itself, and only these antennas, equipped with sensitive receiving equipment with parametric amplifiers, cooled by liquid nitrogen, could detect them.

Diagram of the descent of the "Venus-5" station: 1 - separation of the descent vehicle (DV) from the orbital compartment; 2 - braking of the DV in the atmosphere; 3 - opening of the braking chute; 4 - opening of the main chute, the beginning of the transmission of information from on-board the DV; 5 - beginning of operation of the radio altimeter, scientific measurements; 6 - landing.

How difficult this task is, can be indicated by a comparison, made by one of the creators of these antennas. Let us suppose, - he said, - a glass of boiling water is poured into the Black Sea and you have to with a special thermometer measure, how much the temperature of the sea has risen.

An analogous task was resolved at the Remote Space Communication Center during the carrying out of the near-planetary transmission, and during the fall of the descent vehicle by parachute in the atmosphere of Venus. In the beginning of the transmission onboard the station a number of auxiliary commands were emitted, which prepared the systems of the station for carrying out the final stage of flight. The signals, confirming the performance of each command by the station, arrived on the Earth after 8 minutes.

The last near-planetary radio transmission with the "Venus-5" station was carried out during the approach to the planet Venus for two hours before its entry into the atmosphere. It was begun upon command of the program-time equipment at the time, assigned from the Earth in the previous communication transmission. In the course of the 8 minutes control trajectory measurements for more precise definition of the effect of the gravitational field of Venus and for the introduction of the necessary corrections into the ballistic calculations were performed. Then telemetering information about the state of the onboard systems was transmitted.

The descent vehicle of the "Venus-5" station was separated from the orbital compartment before its entry into the atmosphere of planet at a distance of 37 thousand kilometers, and of the "Venus-6" station - at a distance of 25 thousand kilometers from Venus.

Radio communications with the orbital compartments of the "Venus-5" and "Venus-6" stations was maintained right up to their entry into the dense layers of the atmosphere.

After its entry into the dense layers of the atmosphere (at 0901

Moscow time on May 16, 1969) for the descent vehicle of the "Venus-5" station the most complex stage of its flight was begun - aerodynamic braking. At a velocity of entry into the atmosphere of the planet of an order of 11 kilometers per second the overloads on the vehicle attained 450 units, and the temperature of the gas near its surface reached 11,000°C.

As a result of the aerodynamic braking the vertical velocity of the descent vehicle after a short time had decreased to approximately 210 meters per second. After this during a strictly calculated time period special sensors carried out the activation of the automatic equipment of the descent vehicle, controlling the deployment of the parachute system and the activation of the scientific equipment. The automatic equipment activated the braking, and then the main chutes, the antennas of the radio transmitter, the radio altimeter, and the scientific equipment. The smooth descent of the vehicle in the atmosphere of Venus and the transmission of scientific data to the Earth had begun.

Naturally, during those minutes, when the descent vehicle enveloped by plasma flame entered into hand-to-hand combat with the Venusian atmosphere, there was no communication with it and in the premises of the operational groups and the command area of the Remote Space Communication Center intense silence predominated. And how great was the joy of the people, when on the oscillograph tube there appeared the green light spot of the signal from the descent vehicle and from the loudspeaker there resounded the triumphant voice of the announcer: "We have the signal!".

Radio transmission with the descent vehicle of the "Venus-5" station began at 0902 Moscow time. During the whole time of the descent of the vehicle communication with it was stable. The radio communication transmission lasted 53 minutes. At the moment of the cessation of communications with the descent vehicle of the "Venus-5" station the external atmospheric pressure has attained a value of

approximately 27 atmospheres which was the maximum for the strength of the outer shell of the vehicle. During descent the temperature inside the descent vehicle varied insignificantly: from 13°C in the beginning of the descent portion to 28°C at its end. This attested to the reliability of the external heat shield, which protected the vehicle from the brief, but extremely high heat fluxes, which appear during aerodynamic braking, and the internal heat-insulation layer, which protected the vehicle from heating in the atmosphere of Venus during the long period of the descent by parachute; when the temperature of the atmosphere rose to approximately 300°C.

The communication transmissions during the approach to the planet and during the descent of the "Venus-6" station in the atmosphere of Venus proceeded analogically: the entry into the dense layers of the Venusian atmosphere of the descent vehicle of the "Venus-6" station occured on May 17, at 1905, the radio communication transmissions during the descent by parachute in the atmosphere of planet lasted for 51 minutes.

Investigations Along the Flight Path and in Circumplanetary Space

During the flights along the Earth-Venus path, the automatic stations "Venus-5" and "Venus-6" carried out measurements of solar and galactic cosmic rays, investigations of the interplanetary plasma and scattered ultra-violet solar radiation.

The equipment, mounted on the orbital compartments of the stations for measuring space rays, made it possible to record protons with an energy of from 1 to 12 billion electron volts, and also protons with an energy, greater than 30 million electron volts, and electrons with an energy, greater than 0.1 million electron volts. As the measurements showed, carried out by the "Venus-5" and "Venus-6" stations, the overall level of flux of galactic cosmic rays was lower, than during June-October of 1967 during the flight of the automatic station, "Venus-4", by approximately 15 percent and by approximately 40 percent in comparison with the data, obtained

by the stations, "Zond-3" and "Venus-2", during December of 1965. This is connected with the cyclical activity of the Sun and attests to the reactivated flux of heterogeneous magnetic fields, coming from Sun.

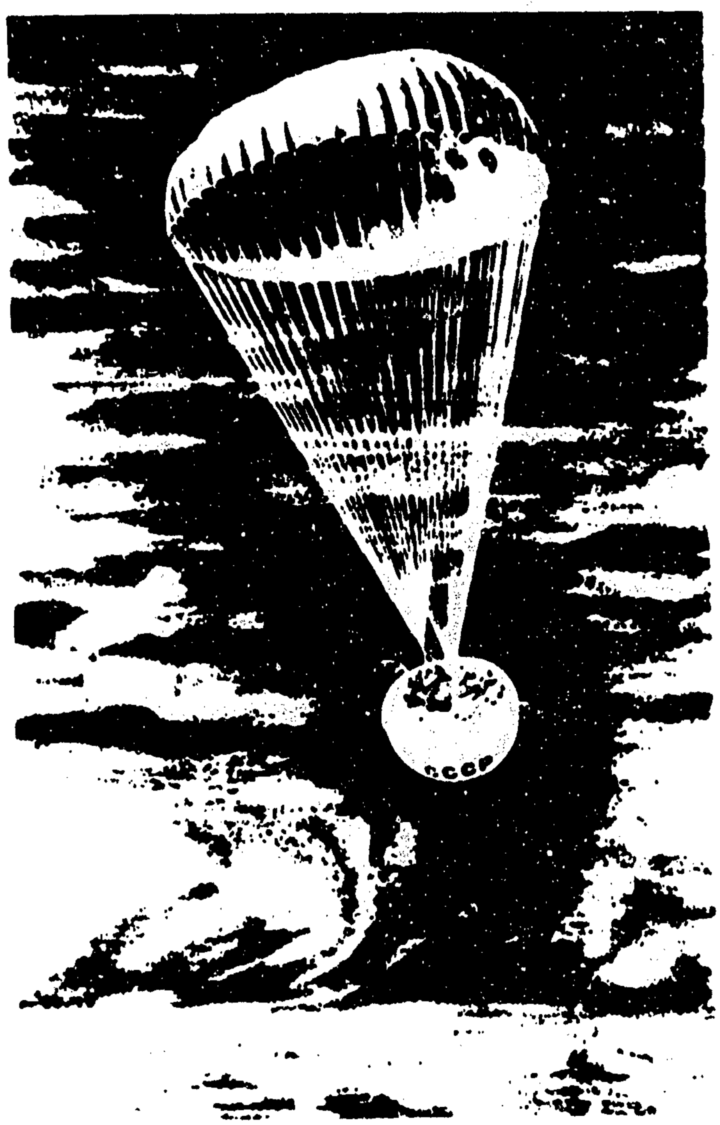
During the flights of the "Venus-5" and "Venus-6" stations a great increase in the intensity of the fluxes of solar protons with an energy of 1-4 million electron volts was recorded, of which 12 were considerable. Four increases in intensity were distinguished by their complex structure and great duration: each of them lasted not less than seven days. The intensity of the fluxes exceeded the level of the galactic background by many times. This can be explained by the revived activity of the Sun, expressed in the appearance of a group of chromospheric flares of great force, which was taking place during this period.

Near Venus new data was received about the structure of the fluxes of circumplanetary plasma. Earlier, during the flights of space vehicles, it was established that interplanetary space was filled with plasma fluxes, having velocities, equal to several hundred kilometers per second. In connection with the fact that plasma fluxes move from the Sun, they received the name, solar wind. This plasma is "magnetized" - it has its own magnetic field.

The interaction of Solar wind with the magnetosphere of the Earth has been well studied by the launchings of artificial earth satellites and of space vehicles, but, how a plasma behaves near a planet which does not have its own magnetic field, before the flights to Venus of the Soviet and American interplanetary stations was not known.

The first acute variations in the concentration of the plasma, connected with the simultaneous variation in the intensity of the magnetic field in the vicinity of Venus, were observed on Octover 18, 1967 with the help of charged particle traps and a magnetometer,

mounted on the Soviet "Venus-4" station. Fluxes of interplanetary plasma were also recorded by "Venus-5" and "Venus-6". The greatest volume of information was received with the aid of traps, mounted on the "Venus-6" station. In the approach of the station to the planet changes in the magnitude of the fluxes and of the plasma were recorded, characteristic for the flowing around of Venus by the solar wind.



The fall of the descent vehicle.

Near the front, where the changes in the fluxes of the plasma occurred, observed at a distance of approximately 28,000 kilometers from the surface of the planet, and the "Venus-4" station intersected this front at a distance of 1900 kilometers from the surface of the planet. This is explained by the fact that the "Venus-5" and "Venus-6" and also the "Venus-4" stations, descended on the night side of the planets, but farther from the terminator, the boundaries of day and night, and therefore the intersection of the front of the acute variation in the flux of charged particles occured at a greater distance from the planet.

The photoelectric photometers for measuring scattered ultra-violet radiation in the vicinity of the planet and in the interplanetary medium, mounted on both stations, showed that, as was also observed in the flight of the "Venus-4" station, the intensity of the radiation in the line of atomic hydrogen increases with the approach to the planet. From the results of the measurements the density of atomic hydrogen in the remote regions of circumplanetary space was calculated. It turned out that the first signs of the presence of a hydrogen corona appeared even at a distance of 25,000 kilometers from the center of the planet and at a distance of about 10,000 kilometers the density of the hydrogen corona was equal to approximately 100 atoms per cubic centimeter.

Investigations in the Atmosphere of Venus

The main task of the robot space stations, "Venus-5" and "Venus-6" was to continue the investigations of the chemical composition and the parameters of the atmosphere of Venus, first begun by the automatic station "Venus-4" in October of 1967. For this on the descent vehicles of the automatic stations there were mounted: pressure and temperature sensor systems, calculated for various ranges of measurements; gas analyzers to investigate the gaseous composition of the atmosphere; density gauge for measuring the density of the atmosphere and for the first time - photocells for measuring illuminance in the atmosphere of Venus.

The gas analyzers carried out measurements of the content of carbon dioxide, oxygen, water and nitrogen together with the inert gases at two different levels above the surface of the planet, consequently, at different pressures and temperatures. The carrying out of the analysis of the composition of the atmosphere was executed upon commands, emitted from the onboard program-time device. Of the numerous possible methods for determining the composition of the atmosphere the simplest and most reliable physico-chemical methods, based upon well studied reactions, having high selectivity, were used.

The system of sensors for measuring the temperature and of pressure consisted of resistance thermometers and aneroid-type manometers.

The mutual over-lap of the ranges of measurements of the instruments ensured the possibility of controlling the correctness of the measurements and their high reliability. For measuring the density of the atmosphere a tuning-fork type instrument was used, the operating principle of which was based on the variation in amplitude of oscillations of a definite frequency depending on the density of the surrounding medium.

For measuring the amount of illuminance in the atmosphere of the planet photoelectric sensors were used, calculated for recording the radiation in the visible and near infra-red range of the spectrum with a threshold sensitivity of 0.5 watt per square meter. This value of illuminance corresponds approximately to the illuminance on Earth in deep twilight.

The advantage of all the indicated instruments is their design simplicity, their small weight and their capability to operate reliably at high values of pressure and temperature.

On the descent vehicles decimeter-range radio altimeters

were mounted. Their operating principle is analogic to the operation of aviation altimeters. With the aid of radio altimeters certain fixed values of distances to the surface of the planet in the descent process were determined. The range of the scales of fixed values of height, which could be recorded by radio altimeters, was included within the limits of from 50 to 10 kilometers. This selection of the operating range of the instruments was based on data, obtained from the "Venus-4" station, and the preliminary calculations of expected moments and heights of the opening of the parachutes. All scientific measurements were carried out in the parachute descent segment of the stations.

The first intake sample of the atmosphere for carrying out its analysis on the "Venus-5" station was accomplished soon after the opening of the main chute, when the pressure was about 0.6 of an atmosphere, and the temperature - about 25°C. The second time a sample was taken at a lesser height, when the pressure was about 5 atmospheres and the temperature about 150°C.

The gas analyzer of the "Venus-6" station also took two samples of the composition of the atmosphere of Venus at different heights. The first sample was taken at a pressure of about 1 atmosphere, when the temperature was approximately 60°C, the second - when the pressure has reached 10 atmospheres, and the temperature 225°C.

The results of the investigation of the composition of the atmosphere of Venus carried out on the "Venus-5" and "Venus-6" automatic stations confirmed and definitized the data, obtained earlier on the "Venus-4" station. Now it is possible to assert that the atmosphere of Venus almost completely consists of carbon dioxide and contains small quantities of nitrogen, water and oxygen. The concentration of carbon dioxide reaches 93-97 percent (on "Venus-4" a value of 90 ± 10 percent was received). The content of nitrogen together with inert gases is 2-5 percent, and the amount of oxygen does not exceed 0.4 percent. These results coincide well with the measurements of "Venus-4", which showed that the nitrogen in the

atmosphere of Venus is less than - 7 percent, and the oxygen - about a half a percent. The content of water vapor at a level of altitudes, corresponding to the pressure of 0.6 atmosphere, is from 4 to 11 milligrams per litre. The measurements, carried out in 1967 by the "Venus-4" station, recorded that at a pressure of about 0.6 atmosphere from 1 to 8 milligrams of water vapor is contained in one litre of the atmosphere. This indicates the absence of the saturation of the atmosphere of Venus with water vapor at the heights, where the measurements were conducted.

The interrogation of the pressure and temperature sensors by the telemetering commutator of the onboard radio complex was carried out on the average of every 40-50 seconds. During the descent of each vehicle by parachute more than 70 pressure measurements and more than 50 temperature measurements were carried out. The temperature and pressure of the atmosphere of Venus in the whole interval of sounding were measured to within several percents.

The "Venus-5" and "Venus-6" stations carried out sounding of the atmosphere in the segments, where the temperature varied from approximately 25 to 320°C, and the pressure from 0.5 to 27 atmospheres. The variation rate of temperature with respect to height in the measurement interval differed little from adiabatic. "Venus-4" in 1967 carried out measurements in a segment, where the temperature varied from 25 to 270°C. This segment corresponded to a variation in pressure of from 0.5 to 18 atmospheres.

On the basis of the results of the measurements of temperature, pressure and the chemical composition segments of the descent of the vehicles in the atmosphere of Venus were calculated, at which measurements of the atmospheric parameters on the moments of the opening of the main chutes were conducted. For "Venus-4" this segment was 36 kilometers, and for "Venus-6" - 38 kilometers.

The differences in the values of the heights, recorded by the radio altimeters at the beginning and the end of the descent,

satisfactorily coincided with the path segments of previous vehicles during their descent by parachute. Calculations of the descent segments of the descent vehicles were carried out proceeding from the condition of hydrostatic equilibrium of the atmosphere with respect to the measured values of temperature and pressure at moments of time, corresponding to obtained recordings of heights, and also using the aerodynamic properties of the vehicles during descent by parachute.

The results of the calculations, made by two independent methods, coincided well with each other.

With respect to the preliminary data the recorded heights on "Venus-5" and also on "Venus-6" with identical values of temperature and pressure lead to values, differing from each other by 12-16 kilometers. According to the data of the radio altimeter of the "Venus-5" station, a pressure of 27 atmospheres corresponded to a height of 24-26 kilometers, and with respect to the data of the radio altimeter of the "Venus-6" station, the same pressure corresponded to a height of 10-12 kilometers. These extremely interesting data will be subjected to further careful study; it is possible, this is connected with considerable unevennesses of relief, because the descents were carried out over different sections of the surface of the planet, being distant from each other by several hundreds of kilometers.

The "Venus-5" and "Venus-6" stations carried out their missions completely and transmitted to Earth data from deeper layers of the atmosphere, than "Venus-4". They made it possible by direct measurements to substantially definitize the chemical composition of the atmosphere of the planet and to obtain reliable values of temperature, pressure and density of its atmosphere in height intervals of about 40 kilometers.

The results of these conducted experiments once more confirmed that Venus possesses a thick, dense atmosphere, consisting mainly

of carbon dioxide, and that it has very high values of pressure and temperature near the surface. Even if subsequently, to the surface of the planet itself, the temperature will vary according to the adiabatic law, then at surface level, determined by the radio altimeter of the "Venus-6" station, the temperature and pressure are 400°C and about 60 atmospheres, but at surface level, determined by the radio altimeter of the "Venus-5" station, these magnitudes will increase even more -- up to 530°C and 140 atmospheres.

The photoelectric sensors, mounted on the stations, did not register an illuminance of the atmosphere of Venus on night side above the threshold value - 0.5 watts per square meter. The exception is the one indication recorded by "Venus-5", corresponding to a level of about 25 watts per square meter, which appeared for approximately 4 minutes before the cessation of radio communication. This fact requires thorough study and clarification.

The results of the new direct measurements in the atmosphere of Venus, carried out by the Soviet "Venus-5" and "Venus-6" automatic stations, are difficult to overestimate. For the first time, there was conducted a joint experiment by two automatic stations, which carried out practically simultaneous deep sounding of the atmosphere of Venus in two neighboring regions of planet.

The unique scientific data obtained will make it possible to learn much about the planet of engimos, to understand the structure of its atmosphere and the processes, which takes place in it.

The assualt on Venus is continuing.

* * *

Systematically and sequentially there is being executed in the Soviet Union a program of investigating outer space and the planets of the solar system with the aid of automatic space vehicles. The

robot space stations, "Venus-5" and "Venus-6", having overcome about 350 million kilometers of outer space, penetrated into the atmosphere of Venus and transmitted new valuable scientific information about this planet.

"The fulfillment of this complex experiment attests to the high level of science and of technology in the Soviet Union", - writes the Warsaw newspaper "Tribune of the People". "The Russians are conducting extremely important scientific experiments. It is impossible to overestimate the scientific value of the transmitted information. These data will help unravel some of the riddles of Venus", - stated the famous English scientist Bernard Lovell.

Naturally this is only the beginning, these are only the first flights to Venus. Further investigations will make it possible to obtain many new interesting data about this closest planet to us which is so unlike the Earth. The joint flight of the "Venus-5" and "Venus-6" stations - a new outstanding victory of Soviet science and technology; this is convincing evidence of the high perfection of Soviet rocket technology and automatic equipment, instrument-making and radio technology, which ensure in all sections of the flights the flawless operation of all the on-board systems of the stations, and the ground equipment.

"A new victory of Russian science and technology in investigating outer space has been gained because of the heroic inspired work of the whole Soviet people, - it is noted in the salutation of the Central Committee of the Communist Party of the Soviet Union, the Presidium of the Supreme Soviet of the USSR and the Council of Ministers of the USSR. - This scientific exploit was accomplished when on the on the whole our country was preparing new labor achievements for the building of communism to note the 100th anniversary since the birth of V. I. Lenin - the creator of the Communist Party of the Soviet Union and the founder of the first state in the world of workers and peasants. To this anniversary is dedicated the outstanding achievements of the workers, technicians, engineers and scientists of our country.

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13. ABSTRACT

~~This~~ book in ~~popular form~~ tells about the next stage of the Soviet program for the investigation of the planet Venus with the aid of the automatic space stations, "Venus-5" and "Venus-6". The reader can follow the whole history of man's investigations of Venus, beginning with the most ancient times and continuing up to the present. He will become acquainted with the flights of the space stations "Venus-1", "Venus 2", "Venus-3" and "Venus-4", which helped to reveal certain mysteries of the planet and simultaneously defined more accurately the possibilities of subsequent investigations. In the flights of the space stations "Venus-5" and "Venus-6" data were received about the atmosphere of Venus and the characteristics of interplanetary space, which enriched man's knowledge of the universe, and these flights were genuine triumphs for Soviet science and technology.

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Venus-4 Venus Probe						

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